Review

Not peer-reviewed version

# Potential Designs for Miniature Distributed Optical Fiber Smart Sensors Systems for Use in Aerospace Flight Vehicles

Graham Wild *

Posted Date: 13 March 2025

doi: 10.20944/preprints202503.0993.v1

Keywords: distributed sensing; Fiber Bragg grating; flight test; hypersonic; structural health monitoring

doi:10.20944/preprints202503.0993.v1



*Review*

# Potential Designs for Miniature Distributed Optical Fiber Smart Sensors Systems for Use in Aerospace Flight Vehicles

**Graham Wild**

School of Science, University of New South Wales (UNSW), Canberra, ACT 2612, Australia; g.wild@unsw.edu.au; Tel.: +612-5114-5221

**Abstract:** This article explores the feasibility of miniaturizing and packaging Fiber Bragg Grating (FBG) based Distributed Optical Fiber Smart Sensors (DOFSS) for future flight trials. It highlights the importance of real-time, high-speed sensing in aerospace, particularly for hypersonic vehicles, and the challenges of conventional system integration. The advantages of FBG technology for structural health monitoring, temperature, and pressure sensing are examined. Potential systems, including light sources, spectral detection, and processing units, are discussed, along with challenges such as temperature fluctuations and vibrations. Innovations in photonic devices, fabrication, and packaging are emphasized, focusing on developing compact and robust FBG interrogation systems. The article proposes designs for integrated photonic circuits in FBG interrogation systems. The trade-offs between miniaturization and performance, considering sensitivity, resolution, and durability are also assessed. Finally, future research directions are outlined to enhance the sensitivity, resolution, and robustness of FBG interrogators while enabling miniaturization and multifunctionality. The article concludes by summarizing the potential for miniaturizing and packaging FBG-based DOFSS for aerospace flight trials.

**Keywords:** distributed sensing; fiber Bragg grating; flight test; hypersonic; structural health monitoring

---

## 1. Introduction

### *1.1. Real-Time, High-Speed Sensing in Aerospace*

The significance of real-time, high-speed sensing in aerospace flight trials, particularly for hypersonic vehicles, cannot be overstated [1]. As the aerospace industry pushes the boundaries of flight technology, especially with the advent of hypersonic vehicles capable of exceeding Mach 5 [2], the need for advanced sensing technologies becomes significant [3]. These vehicles operate under extreme conditions where traditional sensing methods may fail to provide the necessary data for safe and effective operations. Real-time data acquisition and processing allow engineers to monitor vehicle performance, environmental conditions, and structural integrity, which are critical for successful flight trials [4].

High-speed sensing technologies enable the collection of vast amounts of data at unprecedented rates. For instance, the Hypersonic International Flight Research Experimentation (HIFiRE) program has demonstrated the importance of real-time data collection in understanding turbulent shock boundary layer interactions during hypersonic flight [5]. Such interactions can significantly affect vehicle performance and stability, making it essential to capture data in real-time to inform immediate decision-making and adjustments during flight trials. The ability to analyze this data on-the-fly allows for a more agile response to unexpected flight dynamics, ultimately enhancing safety and performance.

The integration of advanced flight computers with multicore processing capabilities has been shown to improve the efficiency of real-time data processing in aerospace applications [6]. These systems can handle complex algorithms that require rapid computation, enabling the analysis of sensor data in real-time. This capability is crucial for hypersonic vehicles, where flight conditions can change rapidly, and timely responses are necessary to maintain control and ensure mission success. The implementation of such technologies not only enhances the reliability of flight trials but also contributes to the development of more sophisticated control systems that can adapt to varying flight conditions.

The importance of real-time sensing extends to structural health monitoring (SHM) as well. The use of Fiber-Bragg Grating (FBG) sensors for monitoring the integrity of critical components in flight vehicles is a prime example [7,8]. These sensors provide continuous feedback on structural performance, allowing engineers to detect potential failures before they lead to catastrophic outcomes. In the context of hypersonic flight, where materials are subjected to extreme thermal and mechanical stresses, real-time monitoring becomes essential for ensuring the safety and longevity of the vehicle [9]. Figure 1 shows the serious consequences that can result from hypersonic failures. Hence, such a systems has been proposed for the Lockheed Martin Common Front End project [10].

**Figure 1.** Crashed hypersonic North American X-15. (Creative Commons).

The challenges posed by hypersonic flight, including high temperatures and pressures, necessitate the development of advanced materials and sensing technologies [11]. For example, the design of thermal protection systems for hypersonic vehicles must account for the extreme conditions encountered during re-entry and flight [12]. Real-time sensing plays a vital role in monitoring the performance of these materials, ensuring that they can withstand the harsh environments without compromising vehicle integrity. Figure 2 illustrates many of the key parameters that need to be monitored.

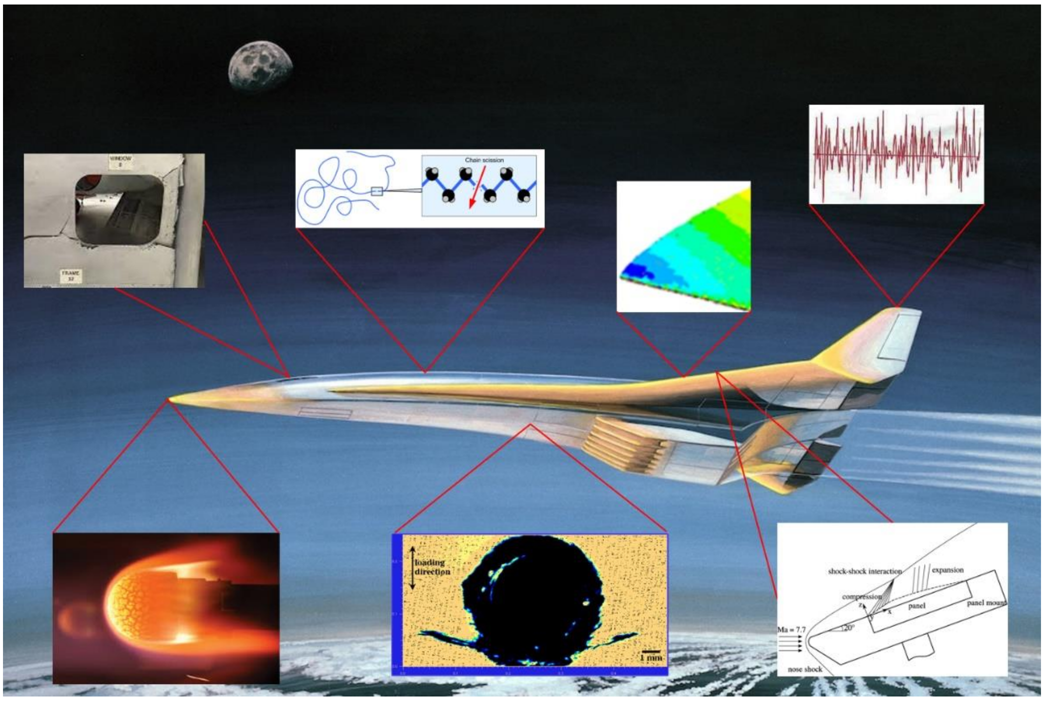


**Figure 2.** Example parameters to be measure during hypersonic flight (clockwise from top left): fatigue, radiation exposure, pressure loads, vibration, fluid-thermal-strucural-interactions, acoustic emissions, thermal effects (temperature and ablations etc). (Creative Commons).

 doi:10.20944/preprints202503.0993.v1



In addition to structural and thermal monitoring, real-time sensing is critical for navigation and control systems in hypersonic vehicles. The dynamic nature of hypersonic flight requires precise control over flight paths and attitudes, which can be achieved through advanced sensing technologies that provide accurate data on vehicle orientation and speed [13]. The integration of these sensors into flight control systems enables the development of more robust and responsive navigation solutions, which are essential for maintaining stability and control during high-speed maneuvers.

### *1.2. Conventional System Integration Challenges*

Deploying conventional interrogation systems in extreme aerospace environments presents challenges that impact performance and reliability, including high temperatures, rapid pressure changes, vibration, and electromagnetic interference. Understanding these challenges is crucial for developing effective sensing technologies.

One primary challenge is extreme temperature fluctuations during flight, especially in high-speed and hypersonic conditions. Conventional systems rely on electronic components that may not withstand high temperatures. Ensuring thermal stability and selecting materials that endure thermal stresses without degrading is essential [14]. Rapid pressure changes during ascent and descent can cause mechanical stress, leading to physical deformation or component failure, compromising data integrity. Designing systems to account for pressure variations may require specialized materials or protective casings [14].

Vibration from aerodynamic forces, engine operation, and turbulence can misalign optical components or degrade signals. Robust mounting solutions and vibration-damping technologies are necessary [14]. Electromagnetic interference (EMI) from strong electromagnetic fields near engines and electronic systems can cause signal noise and data inaccuracies. Shielding and filtering techniques are needed to minimize EMI impact [14].

### *1.3. FBG Technology and Distributed Sensing*

FBGs have emerged as a notable advancement in the field of distributed sensing, offering numerous advantages that make it particularly relevant for various applications, including SHM, temperature measurement, and pressure sensing. The spectral sensing nature of FBGs enables them to function effectively in distributed sensing applications, where multiple sensors can be embedded along a single optical fiber, providing spatially resolved measurements over long distances [15,16].

One of the key advantages of FBG technology is its immunity to EMI, which is a significant concern in many industrial environments. Unlike traditional electrical sensors, FBG sensors operate based on optical signals, making them resistant to noise and interference from external electromagnetic fields [17,18]. This characteristic is particularly beneficial in applications such as SHM of critical infrastructure, where the integrity of the structure must be assessed in the presence of various environmental factors. For instance, FBG sensors have been successfully embedded in composite materials to monitor strain and detect damage, providing real-time data that can inform maintenance decisions and enhance safety [19,20].

The ability to multiplex FBG sensors is another significant advantage that enhances their applicability in distributed sensing systems. Multiple FBG sensors can be placed along a single optical fiber, allowing for the simultaneous measurement of various parameters at different locations without the need for extensive cabling [16,21]. This capability not only reduces installation costs but also simplifies the data acquisition process, making it easier to monitor large structures such as bridges, dams, and buildings. The multiplexing of FBG sensors has been demonstrated in various studies, showcasing their effectiveness in providing comprehensive monitoring solutions for complex structures [22,23].

FBG sensors exhibit high sensitivity and accuracy, which are critical for applications requiring precise measurements. For example, FBG sensors have been utilized to measure temperature and pressure simultaneously in high-speed environments, such as supersonic ejectors, demonstrating their capability to operate effectively under challenging conditions [11,17]. The high sensitivity of

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 13 March 2025 doi:10.20944/preprints202503.0993.v1



FBG sensors allows for the detection of minute changes in strain or temperature, making them suitable for applications in aerospace, civil engineering, and environmental monitoring.

In addition to their technical advantages, FBG sensors are lightweight and compact, which is particularly advantageous in applications where space and weight are critical factors. Their small size allows for easy integration into various structures without adding significant bulk or weight, making them ideal for use in aerospace applications, where every gram counts [18,24]. The lightweight nature of FBG sensors also facilitates their installation in remote or difficult-to-access locations, expanding their potential applications in monitoring systems.

Also, advancements in manufacturing techniques, such as additive manufacturing, have enabled the development of customized FBG sensors tailored for specific applications. This innovation allows for the creation of sensors with enhanced sensitivity or specific response characteristics, further expanding the potential uses of FBG technology in distributed sensing [25,26]. The ability to design and fabricate specialized FBG sensors opens new avenues for research and development, particularly in fields requiring high-performance sensing solutions. These applications, advantages, and technical properties of DOFSS utilizing FBGs are summarized in Table 1.

**Table 1.** Applications, advantages, and technical properties of DOFSS using FBGs.

| Applications | Advantages | Technical Properties |
| --- | --- | --- |
| SHM | Real-time data, damage detection | Embedded in composites, spatial measurements |
| Temperature | High sensitivity, accurate readings | Reflects specific wavelengths, shifts with temperature |
| Pressure | Precise measurements, challenging conditions | Reflects specific wavelengths, shifts with pressure |
| General | Immunity to EMI, lightweight, compact | Optical signals, multiplexing capability |

### *1.4. Aim and Objectives*

The primary aim of this study is to evaluate the feasibility and benefits of deploying FBG based DOFSS in future flight trials. The main objectives are:

- Miniaturization and Packaging: To assess the feasibility of miniaturizing and packaging FBG interrogation systems for aerospace applications.
- Benefits of FBG Technology: To explore the advantages of FBG technology, including immunity to electromagnetic interference, high sensitivity, and accuracy, in aerospace environments.
- Challenges in Extreme Environments: To address the challenges associated with deploying conventional interrogation systems in extreme aerospace conditions, such as temperature fluctuations, vibration, and space constraints.
- Innovations in Photonic Devices: To discuss advancements in photonic devices, fabrication, and packaging that facilitate the development of compact and robust FBG interrogation systems.
- Integrated Photonic Circuits: To propose potential designs for integrated photonic circuits in FBG interrogation systems, emphasizing thermal stability and vibration resistance.
- Trade-offs in Miniaturization: To evaluate the trade-offs between miniaturization and performance in integrated photonic circuits for FBG interrogation, considering factors like sensitivity, resolution, and durability.
- Future Research Directions: To outline future research directions aimed at enhancing the sensitivity, resolution, and robustness of FBG interrogators while enabling miniaturization and multifunctionality.

The remainder of this article is structured as follows: background of FBG technology and distributed sensing. The article then examines potential systems and their components. Innovations in photonic devices, fabrication, and packaging are explored. Potential designs for integrated photonic circuits in FBG interrogation systems are proposed. A feasibility assessment is discussed, along with future research directions.

 doi:10.20944/preprints202503.0993.v1



## 2. FBG-Based DOFSS

FBGs are optical sensors that consist of a periodic modulation of the refractive index along the core of an optical fiber, reflecting specific wavelengths of light while transmitting others [27]. This reflection occurs at the Bragg wavelength, which shifts in response to changes in strain, temperature, or pressure, making FBGs highly effective for sensing applications. The spectral response of FBGs is characterized by parameters such as reflectivity, bandwidth, and sidelobe intensity, which are influenced by the grating length and index modulation. Apodization profiles, like Gaussian and sine, can optimize these spectral characteristics by enhancing reflectivity and minimizing sidelobes [28].

The grating is made up of alternating regions of high and low refractive indices. The periodic grating acts as a filter, reflecting a narrow wavelength range, centered about a peak wavelength. This wavelength is known as the Bragg wavelength, $\lambda_B$, and is given by [29],

$$\lambda_B = 2n\Lambda, \tag{1}$$

where $n$ is the average refractive index of the grating, and $\Lambda$ is the grating period. Any measurand that has the ability to affect either the refractive index or the grating period can be measured using a FBG as a sensor. The change in the measurand will correspond to a change in the Bragg wavelength ($\Delta\lambda_B$), given by,

$$\Delta\lambda_B = \lambda_B\left[\varepsilon\left(1 - \frac{n^2}{2}[p_{12} - \nu(p_{12} + p_{11})]\right) + \Delta T\left(\alpha + \frac{1}{n}\frac{dn}{dT}\right)\right] \tag{2}$$

These measurands typically include strain ($\varepsilon$), change in temperature ($\Delta T$), and pressure data; however, with suitable transduction mechanisms a wide variety of other parameters can be measured. The sensing principle is illustrated in Figure 3.

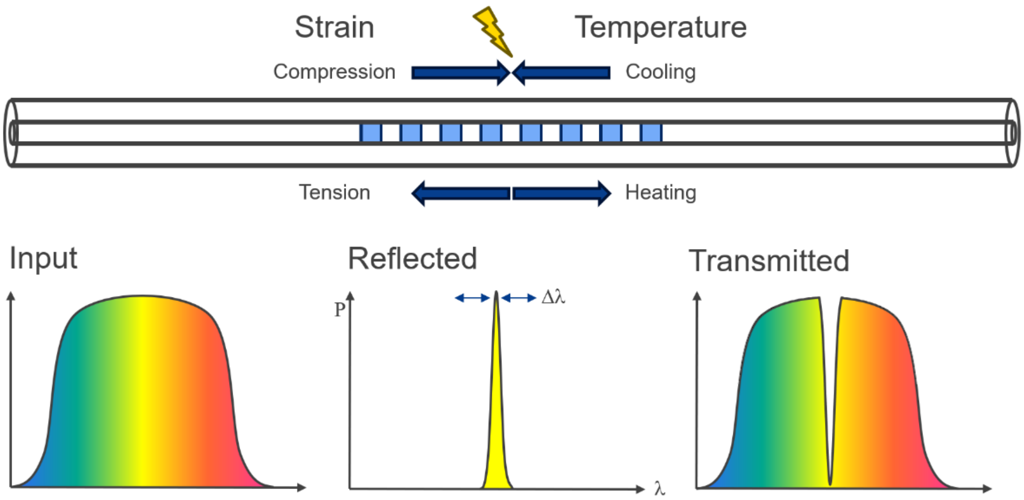


**Figure 3.** FBG Sensor.

DOFSS based on FBGs are a promising technology in aerospace due to their unique advantages [30,31]. Their intrinsic capability to encode mechanical and thermal measurands as shifts in the reflected wavelength, combined with features such as electromagnetic interference immunity, small form factor, and ease of multiplexing, make them particularly well suited for in situ SHM in aerospace environments [32,33]. These features have led to the development of distributed sensor networks that offer quasi-continuous spatial monitoring across composite materials and metallic structures, enabling real-time detection of strain, temperature, displacement, and vibration—all critical parameters for the safety and maintenance of aircraft and spacecraft [34,35].

In aerospace applications, FBG sensors are often embedded directly into load-bearing composite components or integrated onto structural surfaces. For example, in aircraft wing structures, FBG networks have been successfully employed during static load tests and in-flight monitoring to

 doi:10.20944/preprints202503.0993.v1



capture subtle strain distributions and detect incipient damage caused by fatigue or impact events [34,36]. The distributed nature of these sensor arrays allows for multiple sensing points along a single fiber, ensuring that even localized anomalies—such as the initiation of crack propagation or delamination in composite laminates—are promptly identified. This capability is vital for mitigating risks and reducing maintenance costs by pinpointing the location and nature of structural deterioration [33].

The versatility of distributed FBG sensor networks is further demonstrated by their ability to be embedded during the manufacturing processes of composite aerospace components. Such integration not only minimizes the additional weight and complexity associated with conventional sensor systems but also facilitates the real-time monitoring of both production-induced stresses and in-service loads [37]. In addition, dual-parameter sensing approaches allow the decoupling of thermal effects from mechanical strain, resulting in more robust SHM systems that enhance overall vehicle safety and longevity [38,39].

## 3. Potential Systems

### *3.1. System Components*

FBG interrogation systems are sophisticated assemblies that convert the spectral shift of FBGs into measurable physical parameters. These systems are typically composed of three primary components: the light source, the spectral detection unit, and the processing unit. Figure 4

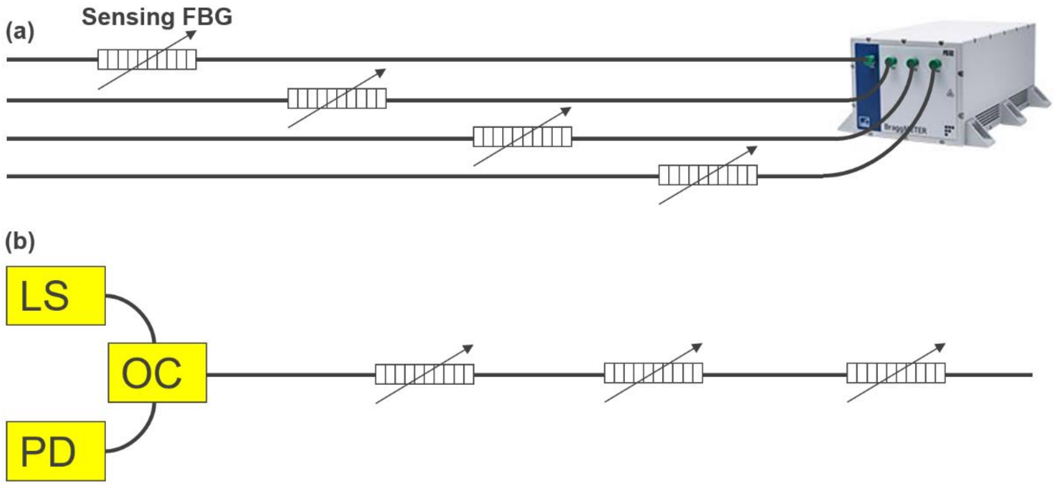


**Figure 4.** FBG sensor interrogation systems: (a) an integrated interrogation system, show with 4 parallel channels; (b) a fundamental schematic with a light source (LS), optical circuitry (OC), and photodetector (PD), with 3 series multiplexed sensors.

A key element in any FBG interrogation system is the light source. It must provide a stable and broadband—or alternatively tunable—optical output suitable for probing the spectral characteristics of the FBG sensors. Broadband sources, such as amplified spontaneous emission (ASE) devices or superluminescent diodes (SLDs), offer the advantage of covering a wide spectral range without the need for mechanical tuning, simplifying the system design for quasi-distributed sensing [40,41]. Conversely, tunable laser sources—including vertical cavity surface emitting lasers (VCSELs) and narrow-linewidth tunable erbium-doped fiber ring lasers—provide the high spectral resolution and dynamic range necessary for applications demanding precise wavelength tracking. These tunable systems facilitate techniques such as time-division multiplexing (TDM) by scanning across a wavelength range and have been successfully demonstrated in dynamic strain measurements [42,43].

The spectral detection unit is responsible for resolving the wavelength shifts induced by environmental or mechanical changes at the FBG sensor. This module typically consists of spectrometers, photodiode arrays, or optoelectronic detectors integrated with optical filters, such as edge filters or Fabry–Perot interferometers. In many systems, the detection scheme is designed to translate small shifts in the Bragg wavelength—encoded in the reflected optical spectrum—into electrical signals with high sensitivity and low noise [44]. Advanced configurations utilize interferometric or radio frequency (RF) detection methods; for example, systems employing RF spectrum analyzers detect beat frequencies corresponding to the spectral shifts, thereby ensuring high-resolution measurement even under rapidly changing conditions [45]. Furthermore, the adoption of innovative optical techniques such as frequency combs and dual-optical frequency comb demodulation schemes has demonstrated enhanced dynamic range and robustness [46].

The processing unit plays a crucial role in converting the raw optical data into useful information regarding the sensed parameters. After spectral detection, the acquired data are digitized and subjected to advanced algorithms to accurately track the Bragg wavelength shifts [46,47]. Field-programmable gate arrays (FPGAs) and digital signal processors (DSPs) are commonly employed to perform real-time signal processing and implement compensation algorithms (including linearity optimization of the demodulation circuitry) so that even minor shifts can be reliably correlated to physical changes [47,48]. This digital processing capability is essential for maintaining system accuracy under varying environmental conditions, ensuring that the final output is both precise and robust for structural health monitoring or other high-performance sensing applications.

### *3.2. System Challenges*

FBG interrogation systems in aerospace applications must operate reliably despite severe environmental challenges. Extreme temperature fluctuations, high vibration levels, and limited available space can adversely affect the performance of key components such as light sources, spectral detection units, and processing electronics.

Temperature fluctuations in aerospace vehicles induce thermal expansion and contraction in optical components, leading to wavelength drifts and instability in laser and broadband light sources. For instance, tunable laser sources and SLDs need precise thermal management because even slight temperature deviations can shift the Bragg wavelength detection windows, thereby compromising strain or temperature measurement accuracy [49]. Moreover, these thermal variations can alter the responsivity of photodetectors in the spectral detection unit, requiring additional calibration and compensation strategies to maintain sensor fidelity [50].

Vibrations present another significant challenge. Aerospace vehicles experience dynamic mechanical stresses during launch, flight maneuvers, and landing. Such vibrations can perturb the optical alignment within spectrometers and fiber couplings, reducing the signal-to-noise ratio by introducing mechanical noise and misalignment factors [50]. When these effects propagate through the optical path, they may generate spurious signals or baseline drifts in the sensor output, thereby degrading the overall system performance.

Space constraints in aerospace further complicate the design of FBG interrogation systems. The limited volume and strict weight budgets necessitate the miniaturization of optical components and electronics without sacrificing performance. Miniaturized systems must integrate light sources, detectors, and processing units into a compact package, often leading to trade-offs between performance, robustness, and power consumption [49]. This demand for highly integrated components drives the need for innovative packaging and system architecture that can endure the challenging aerospace operating conditions.

The solid-state nature of photonics provides a crucial advantage in addressing these challenges. Solid state devices—such as semiconductor lasers, photodiodes, and integrated photonic circuits on platforms like silicon photonics—do not rely on mechanical moving parts; thus, they offer inherent robustness against vibrations and shocks [51]. This intrinsic ruggedness minimizes misalignment issues and reduces the risk of fatigue or component failure under severe vibrational loads. Additionally, the high degree of integration afforded by solid state photonics enables significant reductions in system footprint and weight. Compact, monolithic packaging improves thermal management by facilitating efficient heat dissipation and allows the interrogation unit to maintain

 doi:10.20944/preprints202503.0993.v1



high performance despite the confined spaces typical in aerospace designs [50]. Furthermore, solid state processing units—often implemented on FPGAs or ASICs—exhibit a wide operating temperature range and enhanced resistance to environmental noise, ensuring consistently accurate and rapid signal processing even under extreme conditions [49].

## 4. Innovations

### *4.1. Photonic Devices*

Advances in photonic integration have been significant for light-source design and spectral detection systems. In particular, the integration of tunable lasers and broadband sources onto chip-scale platforms has resulted in compact, robust, and versatile systems capable of meeting the stringent demands of spectroscopy, optical communications, sensing, and imaging.

One major research direction has promoted the integration of tunable lasers across various material platforms. Hybrid integration strategies—such as the incorporation of Semiconductor Optical Amplifiers (SOA) with low-loss silicon nitride (SN) or indium phosphide (InP) waveguides—have enabled extended-cavity laser architectures with wide tuning ranges and ultra-narrow linewidths [52,53]. Monolithic integration approaches, including the demonstration of an erbium-doped tunable laser on a CMOS-compatible silicon photonics platform [54] and heterogeneously integrated quantum dot lasers exhibiting tunable ranges [55], have further consolidated on-chip laser sources for spectroscopic applications. Novel laser concepts, such as topological interface-state lasing in polymer–cholesteric liquid crystal superlattices [56] and nanophotonic crystal structures [57], have provided devices with robustness against perturbations while achieving dynamic spectral control. Other innovative architectures—including optofluidic distributed feedback dye lasers [58,59] and mechanically reconfigurable photonic MEMS devices [60,61]—have introduced additional degrees of freedom in wavelength tuning while reducing thermal dissipation and power consumption.

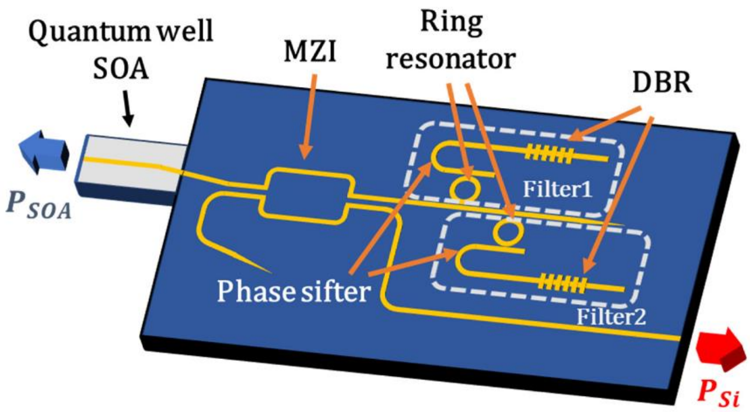


**Figure 5.** Silicon photonic based tunable laser [62]. (Creative Commons).

Significant progress has been made in producing integrated broadband sources [63,64]. Broadband emission is crucial for applications such as hyperspectral imaging and wavelength multiplexing. Supercontinuum generation via cascaded nonlinear interactions in photonic crystal fibers has been long established as a means of covering broad spectral ranges [65,66]. Recent work on on-chip nonlinear optics takes this further by exploiting four-wave mixing and stimulated Brillouin scattering in platforms such as silicon or chalcogenide glass waveguides to generate emission spanning visible to mid-infrared wavelengths [67–69]. Chip-scale broadband sources based on supercontinuum generation have been integrated with waveguide circuits for in situ spectroscopic detection [70] and have been combined with discrete tunable laser elements to enable dual-spectrum operation [71].

Photonic integration has extended into spectral detection. State-of-the-art optical spectrum analyzers (OSAs) realized on silicon or silicon nitride platforms incorporate dispersive elements (e.g., arrayed waveguide gratings and interferometric filters) and photodetectors in a compact format [72].

 doi:10.20944/preprints202503.0993.v1



Such devices benefit from low-cost CMOS-compatible fabrication processes and can be directly integrated with broadband sources or tunable lasers to enable high-resolution, real-time spectroscopy. In addition, tunable laser sources integrated on chip have been exploited for rapid wavelength scanning in spectroscopic sensing applications, which is vital for techniques including Fourier-domain mode locking [73] and quantum cascade laser-based microspectroscopy [74]. Frequency–conversion mechanisms (such as engineered Raman lasing in chalcogenide microresonators [75] and second-harmonic generation in hybrid plasmonic waveguides [76]) further augment the spectral reach of these integrated systems.

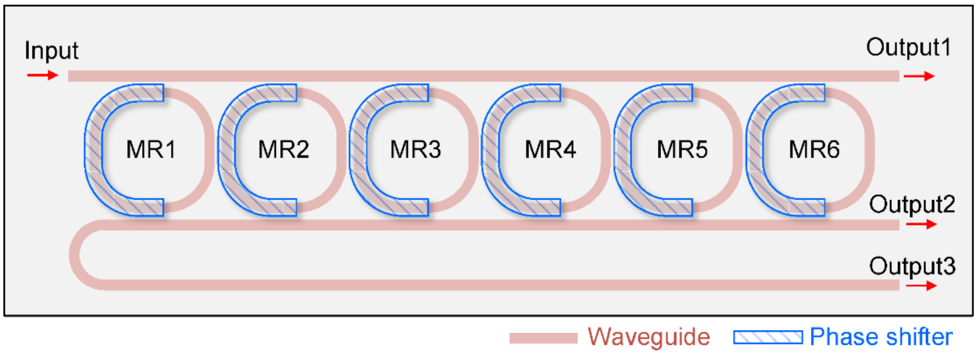


**Figure 6.** Silicon photonic based optical spectrum analyzer based on optical filters [77]. (Creative Commons).

Together, these developments are converging toward fully integrated photonic systems that combine tunable lasers, broadband sources, and spectral detection elements on a single chip. Advances in materials—ranging from traditional III–V semiconductors and silicon to emerging quantum dots, organic semiconductors, and two-dimensional materials [78–81]—are continuously broadening the optical functionality and operational bandwidth of these devices. As integration challenges such as thermal management, wavelength stability, and efficient light coupling are progressively overcome, the resulting miniaturized spectroscopic platforms promise to impact a variety of application areas, including biomedical diagnostics, environmental monitoring, and high-speed optical communications [70,72,82].

### *4.2. Fabrication and Packaging*

Recent progress in the fabrication and packaging of photonic integrated circuits (PICs) has substantially transformed the way optical functionalities are realized on chip-scale platforms. Advances in these areas have focused on both the refinement of material deposition and etching techniques for fabricating high-performance devices, as well as on the development of novel packaging methods that enable the reliable integration of active and passive photonic components.

The advent of hybrid integration methods that leverage thin glass platform technologies to merge traditionally disparate components—for example, vertical-cavity surface-emitting lasers, edge-emitting laser diodes, and photodetectors—onto a common substrate [83]. The thin glass platform not only provides an excellent optical interface but also promotes better alignment tolerance and reduced optical losses, essential for sophisticated photonic systems. Simultaneously, improvements in conventional microfabrication processes, such as room-temperature deposition of dielectrics and superconducting films, have been implemented to produce low-loss waveguides and robust functional layers necessary for integrated photonics [84]. These approaches facilitate the fabrication of components with higher performance and reliability, critical for multichannel and multiplexed applications.

Also, significant progress has been made in photonic packaging techniques that go beyond the chip itself to address system-level challenges. The packaging of PICs is evolving toward methods that integrate optical, electrical, and thermal functionalities into a single module. For instance, techniques involving face-to-face solder reflow bonding and three-dimensional (3-D) integration have been developed to combine photonic and electronic circuits, ensuring not only effective optical coupling but also low-resistance electrical interconnects and efficient thermal dissipation [85,86]. Thermal management, in particular, remains a crucial issue for sensitive photonic devices such as ring resonators and modulators. Innovative strategies like substrate-integrated micro-thermoelectric coolers have been proposed and demonstrated to locally counteract temperature fluctuations, thereby stabilizing device operation and enhancing overall system performance [87].

The integration of many diverse components into a single monolithic platform is another area of rapid advancement. An illustrative example is provided by the work on all-silicon interferometric circuits that incorporate both active light sources and passive filtering elements. Such systems illustrate the potential for lab-on-a-chip devices where disparate optical functions are seamlessly integrated to achieve high spectral resolution and multifunctional operation [88]. This level of integration is fundamental for pursuing applications in optical communications, sensing, and on-chip spectroscopy, where space, performance, and power consumption are all at a premium.

Collectively, these developments highlight the joint nature of advancements in both fabrication and packaging. The integration strategies—whether through the use of novel hybrid materials, low-temperature deposition techniques, or advanced bonding and thermo-mechanical designs—address the multifaceted challenges of aligning, interconnecting, and thermally stabilizing photonic components. As these approaches continue to mature, they promise to further shrink device footprints and enhance the functionality of photonic circuits, paving the way for more robust, scalable, and versatile photonic systems.

## 5. Proposed Designs

### *5.1. Interrogator*

PICs have been effectively utilized in FBG interrogation systems, with numerous studies demonstrating significant advancements in integrating both light sources and detectors onto a single chip. Recent work in silicon photonics has shown that leveraging CMOS compatible fabrication techniques allows researchers to embed not only passive optical components but also active ones—such as tunable lasers and photodetectors—within a compact photonic platform [89,90].

For instance, Zhang et al. [89] provided valuable insights into the development of on-chip silicon photonic integration for FBG interrogators that incorporate algorithms for self-adapting threshold peak detection. This integration reduces overall system complexity and physical footprint while maintaining high interrogation accuracy. Complementing this, Quélène et al. [90] demonstrated a tunable hybrid III-V-on-silicon laser specifically tailored for the spectral characterization of FBG sensors, showcasing how direct integration of a laser source onto a silicon platform not only enhances spectral performance but also significantly reduces the size and cost of the interrogation system.

Marin et al. [91] presented a broader overview of current trends in the field, outlining the evolution of photonic-integrated FBG interrogators. Their review indicates that while some integrated solutions have traditionally incorporated only passive spectral filtering and detection circuitry, modern efforts are increasingly focused on the monolithic integration of both light sources and detectors. Recent demonstrations on the silicon-on-insulator (SOI) platform have featured active phase demodulation techniques coupled with unbalanced Mach-Zehnder interferometers for efficiently converting Bragg wavelength shifts into electrical signals [92].

Elaskar et al. [93] reported on ultracompact designs utilizing microinterferometer-based FBG interrogators on silicon chips. Their research successfully integrated grating couplers, both active and passive interferometers, a multi-channel wavelength-division-multiplexing filter, and Germanium photodetectors, culminating in a fully integrated FBG interrogation scheme. Additionally, Li et al. [94] expanded the applications of integrated photonic interrogation to wearable platforms by incorporating all necessary optical components—including the light source—onto a single photonic chip, thereby creating a miniaturized, low-power interrogator capable of continuously monitoring physiological signals in a wristband format.

 doi:10.20944/preprints202503.0993.v1



Approaches such as planar lightwave circuit (PLC)-based arrayed waveguide grating (AWG) designs for FBG interrogation illustrate the versatility and scalability of integrated photonics in this domain [95]. These various approaches collectively enhance the reduction of system cost, weight, and power consumption while ensuring fast, accurate, and multiplexed interrogation of FBG sensors.

#### 5.1.1. Spectral Receiver Detection

The first FBG interrogation system designed, as illustrated in Figure 7, utilizes a silicon photonic light source comprising an on-chip LED and SOA. This system integrates an on-chip OSA made up of an array of tunable filters. The setup connects to an off-chip optical fiber containing the sensing FBGs via a simple con-chip coupler. This design represents a standard FBG interrogation system based on an OSA, miniaturized and integrated into a single photonic chip, providing a compact and efficient solution for various sensing applications.

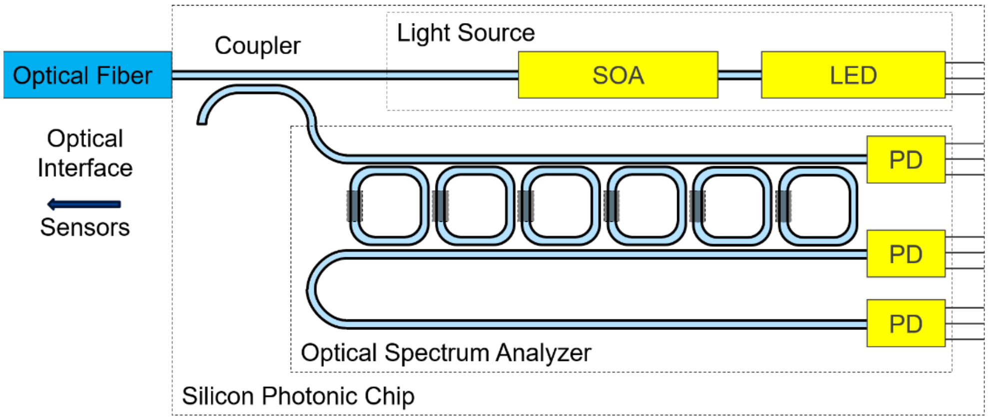


**Figure 7.** FBG sensor interrogation design utilizing an on-chip OSA with a broadband light source.

#### 5.1.2. Spectral Source Detection

The second FBG interrogation system, depicted in Figure 8, employs an alternative arrangement where the spectral shift (wavelength change) is achieved via the optical source. This system utilizes a tunable laser, which consists of an on-chip SOA, a Distributed Bragg Reflector (DBR), and the necessary ring resonator and Mach-Zehnder (MZ) interferometer. Similar to the first design, this setup connects to the off-chip FBGs through an on-chip coupler. The other ports of the coupler are connected to a pair of matched photodetectors, allowing for the monitoring of the laser's output power. This configuration also supports a non-spectral sensing modality based on power detection, which is particularly useful for applications requiring high interrogation frequencies.

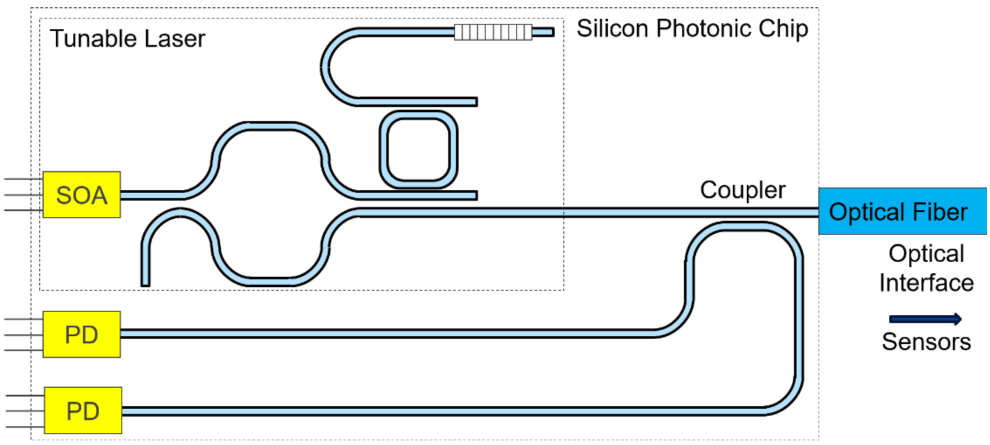


**Figure 8.** FBG sensor interrogation design utilizing an on-chip tunable laser with a pair of matched photodetector.

 doi:10.20944/preprints202503.0993.v1



### 5.2. Thermal Stability and Vibration Resistance

The intrinsic sensitivity of PICs to environmental factors makes the achievement of thermal stability and vibration resistance a crucial design criterion for FBG interrogators. A number of complementary strategies have been implemented and are under active investigation to overcome these challenges.

One primary strategy for enhancing thermal stability is the active compensation of temperature fluctuations. For instance, the use of dual-heater control techniques enables the simultaneous stabilization and tunability of narrowband FBG elements. In these implementations, complementary heating elements are integrated into the photonic circuit so that any temperature-induced wavelength drift is actively counteracted, thereby maintaining the spectral integrity of the interrogator [96]. A related approach involves temperature-independent demodulation schemes using pulse-width modulation, which exploit design architectures that minimize the temperature sensitivity of the demodulation process [97]. Furthermore, the incorporation of functionally graded materials (FGMs) into the packaging of photonic circuits has been proposed to mitigate thermal gradients. FGMs offer a continuous transition in thermal properties within the packaging material, thereby reducing stress and enhancing overall thermal stability [98].

In parallel with thermal management, considerable effort has been devoted to reducing the deleterious effects of mechanical vibration. One effective strategy has been the engineering of photonic packaging structures to achieve high stiffness and intrinsic damping. Chiral metamaterial assemblies have been designed to deliver both high stiffness and considerable damping over low-frequency ranges, making them attractive for integrated packages exposed to mechanical vibrations [99]. Beyond material choices and active control methods, passive stabilization of optical elements within the photonic circuits also plays a key role. Integrated interferometric elements used in FBG interrogation systems are often designed with inherent structural stability to ensure their optical path lengths remain relatively insensitive to mechanical vibrations. Studies employing linear variable filters within FBG sensor interrogators have emphasized the importance of designing compact and mechanically robust modules, particularly in applications where size, weight, and vibration resistance are critical [100,101]. In these systems, passive stabilization techniques complement active thermal control to maintain high interrogation accuracy even under dynamic loading conditions.

## 6. Discussion

### 6.1. Feasibility Assessment

Recent advances in PICs have made it technically feasible to design FBG interrogators that combine high speed with high sensitivity. In several recent studies, researchers have demonstrated that critical functionalities—such as on-chip light sources, high-speed photodetectors, and precise spectral filters—can be monolithically integrated using heterogeneous processes, primarily on silicon platforms. For example, Li et al. [102] have shown a chip-scale demonstration of hybrid III–V/silicon photonic integration where the light source and photodetector are combined with passive filtering elements, thereby enabling FBG interrogation with reduced footprint and improved signal integrity.

In the context of sensitivity, state-of-the-art designs have pushed the boundaries of wavelength resolution. Zhuang et al.[103] provide an example with an on-chip FBG interrogator capable of sub-picometer continuous wavelength tracking, which is integral to detecting the minute spectral shifts caused by environmental changes such as strain or temperature variations. Furthermore, active phase demodulation methods implemented on silicon photonic platforms, as demonstrated by Marin et al. [92], have further enhanced the ability to monitor such small spectral changes with high accuracy, supporting applications that demand both high sensitivity and rapid response.

Complementary interrogation strategies, such as those based on microwave photonic filtering and wavelength-to-time mapping [104], have also been successfully demonstrated. These techniques enable the translation of optical spectral shifts induced by the FBGs into electrical signals with high speed, thus overcoming the speed limitations inherent in many conventional benchtop systems. In addition, AWG approaches for multiplexed FBG interrogation Marrazzo et al. [105] have demonstrated the potential for simultaneous multi-channel sensing with low crosstalk, thereby supporting high-capacity applications in structural health monitoring and aerospace.

A review of the current status and future trends emphasizes that many of these integrated devices are already moving from the laboratory to practical applications [91]. On the horizon, projected advancements—such as further refinement of heterogeneous integration techniques, low-loss silicon nitride waveguides, and improved on-chip packaging strategies—are expected to further enhance both the speed and sensitivity of FBG interrogators. Ultimately, the convergence of these components, along with developments in digital signal processing and CMOS compatibility, suggests that fully integrated, high-speed, and highly sensitive FBG interrogators are not only feasible with current technology but will continue to improve as new materials and fabrication methodologies mature.

### *6.2. Trade-Offs*

Miniaturization in integrated photonic circuits for FB) interrogation offers the significant benefits of reduced footprint, lower power consumption, and potential cost savings. However, as the dimensions of key components such as AWG), interferometers, and photodetectors shrink, trade-offs emerge in terms of sensitivity, resolution, and durability.

A primary concern lies in sensitivity. In chip-scale devices, the reduction of optical path lengths and active interaction volumes can limit the effective signal strength and signal-to-noise ratio. For example, Li et al. [102] demonstrated a hybrid III–V/silicon photonic integrated FBG interrogator that, while compact, faces inherent challenges in maintaining high sensitivity due to the reduced cavity dimensions that limit the necessary optical integration for resolving very small wavelength shifts. In a similar vein, Falak et al. [106] reported on a low-cost FBG interrogation system utilizing a femtosecond laser-written scattering chip, where the miniaturization process involves a trade-off between achieving a compact design and ensuring that the small interaction volumes do not compromise the detection of fine spectral variations.

Resolution is equally affected by miniaturization. High spectral resolution typically requires long optical paths to create sufficient dispersion or interference for precise wavelength discrimination. In integrated platforms, the limited physical separation available in AWG or interferometric structures can restrict the achievable resolution. Marin et al. [92] addressed this issue by implementing active phase demodulation on a silicon photonic platform to enhance wavelength discrimination despite the small device footprint. However, such measures often increase the complexity of the device and may not fully compensate for the resolution loss that is intrinsic to a miniaturized design. Furthermore, Li et al. [107] and Marin et al. [51] demonstrated that while monolithic integration can enable multiplexing to interrogate numerous FBG sensors simultaneously, the closeness of waveguide channels can lead to increased optical crosstalk and limit the spectral bandwidth over which high resolution is maintained.

Durability and long-term stability form a third critical dimension of the trade-off landscape. Miniaturized photonic circuits are inherently more susceptible to environmental perturbations. Thermal fluctuations and mechanical vibrations, which are less problematic in larger, more massive systems, have an amplified effect on small-scale structures. Marin et al. [91] emphasized that robust packaging and sophisticated thermal management strategies become essential to preserve the performance of integrated FBG interrogators under harsh or variable conditions. Similarly, Trita et al. [108] demonstrated that while AWG-based compact interrogators are attractive for their size and integration capabilities, they require careful calibration and resilient packaging to counteract thermal drift and mechanical stress, aspects that can affect both sensitivity and resolution over the long term.

Recent approaches aimed at pushing the performance boundaries of miniaturized systems also highlight additional trade-offs. For instance, Xu et al. [109] exploited dispersion-engineered photonic molecules to break the resolution–bandwidth limit in chip-scale spectrometry, achieving high spectral resolution within a limited footprint. However, this technique introduces increased

 doi:10.20944/preprints202503.0993.v1



fabrication complexity and potential reliability issues. Similarly, Zhang et al. [110] demonstrated a single-shot on-chip diffractive speckle spectrometer with extremely high spectral channel density, yet the compact nature of the device necessitates very tight fabrication tolerances and can make it more vulnerable to performance degradation due to slight manufacturing variations or environmental stresses.

*6.3. Future and Further Research*

Future research on integrated photonic circuit–based FBG interrogators is expected to focus on several key areas that promise to enhance sensitivity, resolution, and robustness while enabling miniaturization and multifunctionality.

A major area of investigation involves advanced materials and novel fabrication techniques. Recent work on lightweight three-dimensional graphene metamaterials with tunable negative thermal expansion demonstrates the potential for regulating internal stress and improving structural stability under thermomechanical coupling [111]. In the context of integrated photonic circuits, such metamaterials may be exploited to alleviate thermal mismatches and reduce temperature-induced drift in FBG interrogators. Similarly, incorporating two-dimensional materials such as $PtSe_2$ via selective and conformal deposition offers the potential to improve device durability and commercial compatibility with low-temperature processing [112]. Additionally, research into self-healing polymer networks and photonic vitrimer elastomers is emerging as a promising approach to enhance long-term reliability by providing intrinsic recovery from mechanical or environmental damage, which is critical for applications in harsh environments [113].

Another promising research axis is the development of novel interrogation architectures and signal processing methodologies. Recent demonstrations of compact high-resolution FBG strain interrogators using laser-written 3D scattering structures indicate that advanced fabrication techniques can reduce device footprint while maintaining high resolution [114]. Concomitantly, the application of machine learning approaches—for instance, CNN-based autoencoder schemes for multipeak wavelength detection of overlapped FBG signals—points toward data-driven interrogation strategies that can enhance both the dynamic range and the noise tolerance of the system [115]. Furthermore, on-chip integration of temperature sensors using InP-based p–i–n diodes and the incorporation of quantum-based photonic sensors are expected to enable real-time compensation for environmental fluctuations while providing ultra-narrow linewidths required for enhanced sensitivity [116,117].

Also, the integration of these interrogators into multifunctional sensor networks and their deployment in extreme environments are gaining considerable attention. Miniaturized FBG interrogator platforms designed for nano-satellite structural health monitoring suggest that future research will extend to aerospace and nuclear applications where high-speed dynamic measurements under severe thermal and vibrational conditions are mandatory [118]. Further exploration of distributed sensing architectures that incorporate wavelength-division multiplexing techniques and sensor fusion methods is anticipated to lead to robust, scalable networks capable of simultaneous strain, temperature, and pressure measurement, thereby broadening the application spectrum of FBG-based optical sensors.

The coupling of advanced signal processing with novel photonic integration is expected to drive future advances. By combining low-noise, narrow-linewidth integrated lasers with adaptive real-time digital processing, future interrogators could achieve unprecedented resolution while mitigating cross-sensitivities among multiple physical parameters [119,120]. Research efforts in this direction are likely to synthesize machine learning–assisted calibration algorithms with integrated photonic circuit designs, ultimately paving the way for multi-parameter sensor fusion systems that are both compact and energy-efficient [121].

Together, these research directions—spanning advanced materials, innovative fabrication, novel interrogation architectures, and integration into multifunctional networks—are set to overcome current limits in sensitivity, durability, and environmental resilience, thereby enabling next-generation FBG interrogators suitable for applications in the structural health evaluation of aerospace vehicles and systems.

## 7. Conclusions

In conclusion, this article has explored the potential for miniaturizing and packaging FBG-based DOFSS for aerospace flight trials, highlighting their significance for real-time, high-speed sensing in hypersonic vehicles and the limitations of conventional systems in extreme aerospace environments. Research indicates that FBG technology offers unique advantages, such as immunity to electromagnetic interference, high sensitivity, and multiplexing capabilities for distributed sensing. Advancements in photonic devices, fabrication, and packaging have enabled the development of compact and robust FBG interrogation systems, with integrated photonic circuits showing great promise for miniaturization. Thermal stability and vibration resistance are crucial design considerations, and ongoing research into advanced materials, novel interrogation architectures, and signal processing methodologies aim to enhance overall system performance. Future research directions include the use of advanced materials like graphene metamaterials and self-healing polymers, the development of novel interrogation architectures, and the integration of FBG interrogators into multifunctional sensor networks. Continued innovation in materials, fabrication, and integration strategies will further enhance the speed and sensitivity of FBG interrogators. The convergence of these components, along with developments in digital signal processing and CMOS compatibility, suggests that fully integrated, high-speed, and highly sensitive FBG interrogators are feasible with current technology and will continue to improve. The development of miniaturized and robust FBG-based DOFSS has significant implications for the future of aerospace sensor technology, providing real-time, high-speed sensing for structural health monitoring, temperature measurement, and pressure sensing, which are critical for the safety and performance of aircraft and spacecraft. Continued research and development efforts are essential to address the remaining challenges in miniaturization, thermal stability, and vibration resistance. Collaboration between researchers, industry partners, and government agencies is crucial to accelerate the translation of these technologies from the laboratory to practical applications. By working together, we can unlock the full potential of FBG-based DOFSS and enable a new generation of aerospace vehicles and systems that are safer, more efficient, and more reliable.

**Funding:** This research was supported by the Air Force Office of Scientific Research under award number FA2386-22-1-4081.Any opinion, finding, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the United States Air Force.

**Data Availability Statement:** No new data were created or analyzed in this study. Data sharing is not applicable to this article.

**Conflicts of Interest:** The authors declare no conflicts of interest.

## References

1. Pollock, L.; Kleine, H.; Neely, A.; Wild, G. Optical Fiber Bragg Grating-Based Measurement of Fluid-Structure Interaction on a Cantilever Panel in High-Speed Flow. *IEEE Access* **2024**, *12*, 101106-101120, doi:10.1109/ACCESS.2024.3430219.
2. Pollock, L.; Wild, G. An examination of high-speed aircraft – Part 1: Past, Present, and Future. *Transport Eng* **2024**, *18*, 100290, doi:10.1016/j.treng.2024.100290.
3. Wild, G.; Pollock, L.; Abdelwahab, A.K.; Murray, J. The Need for Aerospace Structural Health Monitoring: A review of aircraft fatigue accidents. *International Journal of Prognostics and Health Management* **2021**, *12*, doi:10.36001/ijphm.2021.v12i3.2368.
4. Tutty, M.G.; Joiner, K. A T&E Code of Practice. In *AIAA SCITECH 2025 Forum*; AIAA SciTech Forum; American Institute of Aeronautics and Astronautics: 2025.

5. Kimmel, R.L.; Prabhu, D.K. HIFiRE-1 Turbulent Shock Boundary Layer Interaction -Flight Data and Computations. In *45th AIAA Fluid Dynamics Conference*; AIAA AVIATION Forum; American Institute of Aeronautics and Astronautics: 2015.
6. Solé, M.; Wolf, J.; Rodriguez, I.; Jover, A.; Trompouki, M.M.; Kosmidis, L.; Steenari, D. Evaluation of the Multicore Performance Capabilities of the Next Generation Flight Computers. In Proceedings of the 2023 IEEE/AIAA 42nd Digital Avionics Systems Conference (DASC), 1-5 Oct. 2023, 2023; pp. 1-10.
7. Ciminello, M.; Sikorski, B.; Galasso, B.; Pellone, L.; Mercurio, U.; Concilio, A.; Apuleo, G.; Cozzolino, A.; Kressel, I.; Shoham, S.; et al. Preliminary Results of a Structural Health Monitoring System Application for Real-Time Debonding Detection on a Full-Scale Composite Spar. *Sensors* **2023**, *23*, 455.
8. Iadicicco, A.; Natale, D.; Di Palma, P.; Spinaci, F.; Apicella, A.; Campopiano, S. Strain Monitoring of a Composite Drag Strut in Aircraft Landing Gear by Fiber Bragg Grating Sensors. *Sensors* **2019**, *19*, 2239.
9. Pollock, L.; Wild, G. An Exploration of Structural Health Monitoring for Hypersonic Vehicles. In *AIAA AVIATION FORUM AND ASCEND 2024*; AIAA Aviation Forum and ASCEND co-located Conference Proceedings; American Institute of Aeronautics and Astronautics: 2024.
10. Giannelis, N.F.; Luppino, J.; Cousens, S.; Eldridge, M.; Smith, J.; Van Pelt, H.; Wild, G.; Neely, A.J.; Beinke, S.K.; Gorin, S. The Common Front End: A Testbed Concept for High-Speed Technology Maturation. In *AIAA SCITECH 2025 Forum*; AIAA SciTech Forum; American Institute of Aeronautics and Astronautics: 2025.
11. Guru Prasad, A.S.; Sharath, U.; Nagarjun, V.; Hegde, G.M.; Asokan, S. Measurement of temperature and pressure on the surface of a blunt cone using FBG sensor in hypersonic wind tunnel. *Measurement Science and Technology* **2013**, *24*, 095302, doi:10.1088/0957-0233/24/9/095302.
12. Reimer, T.; Di Martino, G.; Petkov, I.; Dauth, L.; Baier, L.; Gülhan, A. Design, Manufacturing and Assembly of the STORT Hypersonic Flight Experiment Thermal Protection System. In *25th AIAA International Space Planes and Hypersonic Systems and Technologies Conference*; International Space Planes and Hypersonic Systems and Technologies Conferences; American Institute of Aeronautics and Astronautics: 2023.
13. Guo, J.; Wang, J.; Guo, Z.; Su, Y. Attitude optimization control of hypersonic flight vehicle considering partially unknown control direction. *T I Meas Control* **2022**, *45*, 1337-1350, doi:10.1177/01423312221138124.
14. Ogunleye, R.O.; Rusnáková, S.; Javořík, J.; Žaludek, M.; Kotlánová, B. Advanced Sensors and Sensing Systems for Structural Health Monitoring in Aerospace Composites. *Adv Eng Mater* **2024**, *26*, 2401745, doi:https://doi.org/10.1002/adem.202401745.
15. Chilelli, S.K.; Schomer, J.J.; Dapino, M.J. Detection of Crack Initiation and Growth Using Fiber Bragg Grating Sensors Embedded into Metal Structures through Ultrasonic Additive Manufacturing. *Sensors* **2019**, *19*, 4917.
16. Wang, G.; Zeng, J.; Mu, H.; Liang, D. Fiber Bragg grating sensor network optimization. *Photonic Sensors* **2015**, *5*, 116-122, doi:10.1007/s13320-015-0195-6.
17. Hegde, G.; Himakar, B.; Rao M V, S.; Hegde, G.; Asokan, S. Simultaneous measurement of pressure and temperature in a supersonic ejector using FBG sensors. *Measurement Science and Technology* **2022**, *33*, 125111, doi:10.1088/1361-6501/ac8a0a.
18. Wang, T.; He, D.; Wang, Z.; Quan, Y.; Wang, P.; Wang, Y. Strain test of metalwork using FBG and FEA. In Proceedings of the 2011 International Conference on Electronics, Communications and Control (ICECC), 9-11 Sept. 2011, 2011; pp. 2857-2860.
19. Karatas, C.; Degerliyurt, B.; Yaman, Y.; Sahin, M. Fibre Bragg grating sensor applications for structural health monitoring. *Aircr Eng Aerosp Tec* **2018**, *92*, 355-367, doi:10.1108/AEAT-11-2017-0255.
20. Nicolas, M.J.; Sullivan, R.W.; Richards, W.L. Large Scale Applications Using FBG Sensors: Determination of In-Flight Loads and Shape of a Composite Aircraft Wing. *Aerospace* **2016**, *3*, 18.
21. Ankita, R.; Ghorai, S.K.; Sengupta, S. Vehicle flow indication and identification using FBG sensors. *Phys Scripta* **2024**, *99*, 125543, doi:10.1088/1402-4896/ad8f6c.
22. Chen, S.-Z.; Feng, D.-C.; Han, W.-S. Comparative Study of Damage Detection Methods Based on Long-Gauge FBG for Highway Bridges. *Sensors* **2020**, *20*, 3623.
23. Soman, R.; Balasubramaniam, K.; Golestani, A.; Karpiński, M.; Malinowski, P. A Two-Step Guided Waves Based Damage Localization Technique Using Optical Fiber Sensors. *Sensors* **2020**, *20*, 5804.

24. Liu, B.; Zhang, S.; He, J. Deformation Measurement of Glass Structure Using FBG Sensor. *Photonic Sensors* **2019**, *9*, 367-375, doi:10.1007/s13320-019-0534-0.
25. Yu, Y.; Liu, B.; Xia, F. Design Optimization of Sensitivity-Enhanced Structure for Fiber Bragg Grating Acoustic Emission Sensor Based on Additive Manufacturing. *Sensors* **2022**, *22*, 416.
26. Zhong, H.; Liu, X.; Fu, C.; Xu, B.; He, J.; Li, P.; Meng, Y.; Du, C.; Chen, L.; Tang, J.; et al. Quasi-Distributed Temperature and Strain Sensors Based on Series-Integrated Fiber Bragg Gratings. *Nanomaterials* **2022**, *12*, 1540.
27. Wild, G.; Hinckley, S. Acousto-Ultrasonic Optical Fiber Sensors: Overview and State-of-the-Art. *Sensors Journal, IEEE* **2008**, *8*, 1184-1193, doi:10.1109/JSEN.2008.926894.
28. Maiti, S.; Singh, V. Performance Analysis of Apodized Fiber Bragg Gratings for Sensing Applications. *Silicon* **2022**, *14*, 581-587, doi:10.1007/s12633-020-00852-0.
29. Othonos, A.; Kalli, K. *Fiber Bragg Gratings: Fundamentals and Applications in Telecommunications and Sensing*; Artech House: 1999.
30. Wild, G.; Hinckley, S. Distributed optical fibre smart sensors for Structural Health Monitoring: A Smart Transducer Interface Module. In Proceedings of the 2009 International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), 7-10 Dec. 2009, 2009; pp. 373-378.
31. Wild, G.; Allwood, G.; Hinckley, S. Distributed sensing, communications, and power in optical Fibre Smart Sensor networks for structural health monitoring. In Proceedings of the 2010 Sixth International Conference on Intelligent Sensors, Sensor Networks and Information Processing, 7-10 Dec. 2010, 2010; pp. 139-144.
32. Porins, J.; Bobrovs, V.; Spolitis, S.; Braunfelds, J. Fiber Bragg Grating Sensors Integration in Fiber Optical Systems. In *Application of Optical Fiber in Engineering*, Harun, S.W., Ed.; IntechOpen: Rijeka, 2020.
33. Jasjot, K.S.; Neena, G.; Divya, D. Fiber Bragg grating sensors for monitoring of physical parameters: a comprehensive review. *Opt Eng* **2020**, *59*, 060901, doi:10.1117/1.OE.59.6.060901.
34. Kim, J.-H.; Park, Y.; Kim, Y.-Y.; Shrestha, P.; Kim, C.-G. Aircraft health and usage monitoring system for in-flight strain measurement of a wing structure. *Vtt Symp* **2015**, *24*, 105003, doi:10.1088/0964-1726/24/10/105003.
35. Guo, H.; Xiao, G.; Mrad, N.; Yao, J. Fiber Optic Sensors for Structural Health Monitoring of Air Platforms. *Sensors* **2011**, *11*, 3687-3705.
36. Dvorak, M.; Kabrt, M.; Růžička, M. The Use of Fiber Bragg Grating Sensors during the Static Load Test of a Composite Wing Structure. *Appl Mech Mater* **2013**, *486*, 102-105, doi:10.4028/www.scientific.net/amm.486.102.
37. Krenz, A.; Koch, J.; Reimer, V.; Doering, A.; Guehlke, P.; Waltermann, C. Methods for fbg sensor integration for rtm process monitoring and shm of the final cfrp component. In Proceedings of the 10th ECCOMAS Thematic Conference on Smart Structures and Materials, Patras, Greece, July 3-5, 2023; pp. 1839-1850.
38. Aimasso, A.; Dalla Vedova, M.D.L.; Maggiore, P.; Quattrocchi, G. Study of FBG-based optical sensors for thermal measurements in aerospace applications. *Journal of Physics: Conference Series* **2022**, *2293*, 012006, doi:10.1088/1742-6596/2293/1/012006.
39. Sun, J.X.; Ji, Y.D.; Wang, J.H.; Yin, Y.Z.; Tian, H. Impact Damage Monitoring of Laminated Composites Using FBG Sensors. *Advanced Materials Research* **2011**, *239-242*, 259-262, doi:10.4028/www.scientific.net/amr.239-242.259.
40. Sadık, Ş.A.; Durak, F.E.; Altuncu, A. Fiber Bragg Grating Sensor Interrogation Using Tunable Erbium-Doped Fiber Ring Laser Source. *Sakarya University Journal of Science* **2021**, *25*, 349-356, doi:10.16984/saufenbilder.789433.
41. Lobo Ribeiro, A.B.; Ferreira, L.A.; Santos, J.L.; Jackson, D.A. Analysis of the reflective-matched fiber Bragg grating sensing interrogationscheme. *Appl Optics* **1997**, *36*, 934-939, doi:10.1364/AO.36.000934.
42. Chan, C.C.; Jin, W.; Demokan, M.S. Experimental investigation of a 4-FBG TDM sensor array with a tunable laser source. *Microw Opt Techn Let* **2002**, *33*, 435-437, doi:https://doi.org/10.1002/mop.10343.
43. Huang, Y.H.; Chao, L.; Wai, P.K.A.; Tam, H.Y. Fast FBG sensor interrogation system using vertical cavity surface emitting laser source. In Proceedings of the 2009 14th OptoElectronics and Communications Conference, 13-17 July 2009, 2009; pp. 1-2.
44. Graham, W.; Steven, R. Analytical modeling of power detection-based interrogation methods for fiber Bragg grating sensors for system optimization. *Opt Eng* **2015**, *54*, 097109, doi:10.1117/1.OE.54.9.097109.

45. Muhammad, F.D.; Zulkifli, M.Z.; Harun, S.W.; Ahmad, H. High resolution interrogation system for fiber Bragg grating (FBG) sensor application using radio frequency spectrum analyser. *Aip Conf Proc* **2013**, *1528*, 444-449, doi:10.1063/1.4803642.
46. Hervás, J.; Tosi, D.; García-Miquel, H.; Barrera, D.; Fernández-Pousa, C.R.; Sales, S. KLT-Based Interrogation Technique for FBG Multiplexed Sensor Tracking. *J Lightwave Technol* **2017**, *35*, 3387-3392, doi:10.1109/JLT.2016.2613131.
47. Tosi, D. Improved KLT Algorithm for High-Precision Wavelength Tracking of Optical Fiber Bragg Grating Sensors. *Journal of Sensors* **2017**, *2017*, 5412825, doi:https://doi.org/10.1155/2017/5412825.
48. Li, D.-s.; Sui, Q.-m.; Cao, Y.-q. Linearity optimization of edge filter demodulators in FBGs. *Optoelectronics Letters* **2008**, *4*, 193-195, doi:10.1007/s11801-008-8001-y.
49. Aimasso, A.; Dalla Vedova, M.D.L.; Bertone, M.; Maggiore, P. Preliminary design and performance evaluation of optical fiber-based load sensor for aerospace systems. *Journal of Physics: Conference Series* **2024**, *2802*, 012010, doi:10.1088/1742-6596/2802/1/012010.
50. Brewer, R. High Reliability Electronics for Demanding Aircraft Applications -- An Overview. In Proceedings of the International Conference on High Temperature Electronics, Albuquerque, NM, May 10-12, 2016; pp. 11-17.
51. Marin, Y.; Celik, A.; Faralli, S.; Adelmini, L.; Kopp, C.; Di Pasquale, F.; Oton, C.J. Silicon Photonic Chip for Dynamic Wavelength Division Multiplexed FBG Sensors Interrogation. In Proceedings of the 26th International Conference on Optical Fiber Sensors, Lausanne, 2018/09/24, 2018; p. ThE45.
52. Albert van, R.; Wilson, T.; Ian van den, V.; Fathema, F.; Rob, E.M.L.; Ilka, V.; Chris, G.H.R.; Sami, M.; Dimitri, G. High-power 150 mW extended cavity Si3N4 tunable narrow-linewidth laser. In Proceedings of the Proc.SPIE, 2024; p. 128920J.
53. Fan, Y.; van Rees, A.; van der Slot, P.J.M.; Mak, J.; Oldenbeuving, R.M.; Hoekman, M.; Geskus, D.; Roeloffzen, C.G.H.; Boller, K.-J. Hybrid integrated InP-Si3N4 diode laser with a 40-Hz intrinsic linewidth. *Opt Express* **2020**, *28*, 21713-21728, doi:10.1364/OE.398906.
54. Li, N.; Vermeulen, D.; Su, Z.; Magden, E.S.; Xin, M.; Singh, N.; Ruocco, A.; Notaros, J.; Poulton, C.V.; Timurdogan, E.; et al. Monolithically integrated erbium-doped tunable laser on a CMOS-compatible silicon photonics platform. *Opt Express* **2018**, *26*, 16200-16211, doi:10.1364/OE.26.016200.
55. Kita, T.; Yamamoto, N.; Matsumoto, A.; Kawanishi, T.; Yamada, H. Heterogeneous quantum dot/silicon photonics-based wavelength-tunable laser diode with a 44 nm wavelength-tuning range. *Jpn J Appl Phys* **2016**, *55*, 04EH11, doi:10.7567/JJAP.55.04EH11.
56. Wang, Y.; Yang, D.; Gao, S.; Zhang, X.; Drevensek-Olenik, I.; Wu, Q.; Chemingui, M.; Chen, Z.; Xu, J. Topological Interface-state Lasing in a Polymer-Cholesteric Liquid Crystal Superlattice. *arXiv preprint arXiv:2205.06536* **2022**.
57. Kamp, M.; Scherer, H.; Janiak, K.; Heidrich, H.; Brenot, R.; Duan, G.H.; Benisty, H.; Forchel, A. Nanophotonic integrated lasers. In Proceedings of the Proc.SPIE, 2007; p. 64750Z.
58. Gersborg-Hansen, M.; Kristensen, A. Tunable Optofluidic Third Order DFB Dye Laser. In Proceedings of the 2007 Conference on Lasers and Electro-Optics (CLEO), 6-11 May 2007, 2007; pp. 1-2.
59. Feng, H.; Zhang, J.; Shu, W.; Bai, X.; Song, L.; Chen, Y. Highly Accurate Pneumatically Tunable Optofluidic Distributed Feedback Dye Lasers. *Micromachines* **2024**, *15*, doi:10.3390/mi15010068.
60. Liu, A.Q.; Zhang, X.M. Photonic MEMS: From Laser Physics to Cell Biology. In Proceedings of the TRANSDUCERS 2007 - 2007 International Solid-State Sensors, Actuators and Microsystems Conference, 10-14 June 2007, 2007; pp. 2485-2488.
61. Du, H.; Chau, F.S.; Zhou, G. Mechanically-Tunable Photonic Devices with On-Chip Integrated MEMS/NEMS Actuators. *Micromachines* **2016**, *7*, 69.
62. Tomimura, Y.; Satou, A.; Kita, T. Generation of Millimeter Waves and Sub-Terahertz Waves Using a Two-Wavelength Tunable Laser for a Terahertz Wave Transceiver. *Photonics* **2024**, *11*, 811.
63. Roelkens, G.; Abassi, A.; Cardile, P.; Dave, U.; De Groote, A.; De Koninck, Y.; Dhoore, S.; Fu, X.; Gassenq, A.; Hattasan, N.; et al. III-V-on-Silicon Photonic Devices for Optical Communication and Sensing. *Photonics* **2015**, *2*, 969-1004.

64. De Groote, A.; Peters, J.D.; Davenport, M.L.; Heck, M.J.R.; Baets, R.; Roelkens, G.; Bowers, J.E. Heterogeneously integrated III–V-on-silicon multibandgap superluminescent light-emitting diode with 290  nm optical bandwidth. *Opt Lett* **2014**, *39*, 4784-4787, doi:10.1364/OL.39.004784.
65. Liu, B.W.; Hu, M.L.; Fang, X.H.; Wu, Y.Z.; Song, Y.J.; Chai, L.; Wang, C.Y.; Zheltikov, A.M. High-power wavelength-tunable photonic-crystal-fiber-based oscillator-amplifier-frequency-shifter femtosecond laser system and its applications for material microprocessing. *Laser Phys Lett* **2009**, *6*, 44, doi:10.1002/lapl.200810084.
66. Fedotov, A.B.; Sidorov-Biryukov, D.A.; Ivanov, A.A.; Alfimov, M.V.; Beloglazov, V.I.; Skibina, N.B.; Sun, C.-K.; Zheltikov, A.M. Soft-glass photonic-crystal fibers for frequency shifting and white-light spectral superbroadening of femtosecond Cr:forsterite laser pulses. *J. Opt. Soc. Am. B* **2006**, *23*, 1471-1477, doi:10.1364/JOSAB.23.001471.
67. Eggleton, B. Stimulated Brillouin scattering in photonic integrated circuits: Fundamentals and applications. In Proceedings of the 2015 IEEE Summer Topicals Meeting Series (SUM), 13-15 July 2015, 2015; pp. 84-85.
68. Signorini, S.; Finazzer, M.; Bernard, M.; Ghulinyan, M.; Pucker, G.; Pavesi, L. Silicon Photonics Chip for Inter-modal Four Wave Mixing on a Broad Wavelength Range. *Aip Conf Proc* **2019**, *7*, doi:10.3389/fphy.2019.00128.
69. Kowligy, A.S.; Hickstein, D.D.; Lind, A.; Carlson, D.R.; Timmers, H.; Nader, N.; Maser, D.L.; Westly, D.; Srinivasan, K.; Papp, S.B.; et al. Tunable mid-infrared generation via wide-band four-wave mixing in silicon nitride waveguides. *Opt Lett* **2018**, *43*, 4220-4223, doi:10.1364/OL.43.004220.
70. Du, Q.; Luo, Z.; Zhong, H.; Zhang, Y.; Huang, Y.; Du, T.; Zhang, W.; Gu, T.; Hu, J. Chip-scale broadband spectroscopic chemical sensing using an integrated supercontinuum source in a chalcogenide glass waveguide. *Photon. Res.* **2018**, *6*, 506-510, doi:10.1364/PRJ.6.000506.
71. Benedikt, W.G.; Zhi, J.; Haohua, T.; Stephen, A.B.M.D. Dual-spectrum laser source based on fiber continuum generation for integrated optical coherence and multiphoton microscopy. *J Biomed Opt* **2009**, *14*, 034019, doi:10.1117/1.3147422.
72. Subramanian, A.Z.; Ryckeboer, E.; Dhakal, A.; Peyskens, F.; Malik, A.; Kuyken, B.; Zhao, H.; Pathak, S.; Ruocco, A.; De Groote, A.; et al. Silicon and silicon nitride photonic circuits for spectroscopic sensing on-a-chip [Invited]. *Photon. Res.* **2015**, *3*, B47-B59, doi:10.1364/PRJ.3.000B47.
73. Tang, J.; Zhu, B.; Zhang, W.; Li, M.; Pan, S.; Yao, J. Hybrid Fourier-domain mode-locked laser for ultra-wideband linearly chirped microwave waveform generation. *Nat Commun* **2020**, *11*, 3814, doi:10.1038/s41467-020-17264-8.
74. Kole, M.R.; Reddy, R.K.; Schulmerich, M.V.; Gelber, M.K.; Bhargava, R. Discrete Frequency Infrared Microspectroscopy and Imaging with a Tunable Quantum Cascade Laser. *Anal Chem* **2012**, *84*, 10366-10372, doi:10.1021/ac302513f.
75. Xia, D.; Huang, Y.; Zhang, B.; Zeng, P.; Zhao, J.; Yang, Z.; Sun, S.; Luo, L.; Hu, G.; Liu, D.; et al. Engineered Raman Lasing in Photonic Integrated Chalcogenide Microresonators. *Laser Photonics Rev* **2022**, *16*, 2100443, doi:https://doi.org/10.1002/lpor.202100443.
76. Shi, J.; Li, Y.; Kang, M.; He, X.; Halas, N.J.; Nordlander, P.; Zhang, S.; Xu, H. Efficient Second Harmonic Generation in a Hybrid Plasmonic Waveguide by Mode Interactions. *Nano Lett* **2019**, *19*, 3838-3845, doi:10.1021/acs.nanolett.9b01004.
77. Zhang, Z.; Huang, B.; Zhang, Z.; Chen, H. On-Chip Reconstructive Spectrometer Based on Parallel Cascaded Micro-Ring Resonators. *Applied Sciences* **2024**, *14*, 4886.
78. Zhang, C.; Zhang, C.; Li, Y.; Shi, Y.; Chao, J.; Zhao, Y.; Yang, H.; Fu, B. Wavelength-tunable broadband lasers based on nanomaterials. *Nanotechnology* **2023**, *34*, 492001, doi:10.1088/1361-6528/acf66d.
79. Zhang, W.; Yao, J.; Zhao, Y.S. Organic Micro/Nanoscale Lasers. *Accounts Chem Res* **2016**, *49*, 1691-1700, doi:10.1021/acs.accounts.6b00209.
80. Guo, J.; Huang, D.; Zhang, Y.; Yao, H.; Wang, Y.; Zhang, F.; Wang, R.; Ge, Y.; Song, Y.; Guo, Z.; et al. 2D GeP as a Novel Broadband Nonlinear Optical Material for Ultrafast Photonics. *Laser Photonics Rev* **2019**, *13*, 1900123, doi:https://doi.org/10.1002/lpor.201900123.

81. Zhao, X.; Jin, H.; Liu, J.; Chao, J.; Liu, T.; Zhang, H.; Wang, G.; Lyu, W.; Wageh, S.; Al-Hartomy, O.A.; et al. Integration and Applications of Nanomaterials for Ultrafast Photonics. *Laser Photonics Rev* **2022**, *16*, 2200386, doi:https://doi.org/10.1002/lpor.202200386.
82. Jiang, R.; Mou, D.; Wu, Y.; Huang, L.; McMillen, C.D.; Kolis, J.; Giesber, H.G., III; Egan, J.J.; Kaminski, A. Tunable vacuum ultraviolet laser based spectrometer for angle resolved photoemission spectroscopy. *Rev Sci Instrum* **2014**, *85*, 033902, doi:10.1063/1.4867517.
83. Henning, S.; Julian, S.; Gunnar, B.; Vanessa, Z. Hybrid photonic system integration using thin glass platform technology. *Journal of Optical Microsystems* **2021**, *1*, 033501, doi:10.1117/1.JOM.1.3.033501.
84. Shainline, J.M.; Buckley, S.M.; Nader, N.; Gentry, C.M.; Cossel, K.C.; Cleary, J.W.; Popović, M.; Newbury, N.R.; Nam, S.W.; Mirin, R.P. Room-temperature-deposited dielectrics and superconductors for integrated photonics. *Opt Express* **2017**, *25*, 10322-10334, doi:10.1364/OE.25.010322.
85. Carroll, L.; Lee, J.-S.; Scarcella, C.; Gradkowski, K.; Duperron, M.; Lu, H.; Zhao, Y.; Eason, C.; Morrissey, P.; Rensing, M.; et al. Photonic Packaging: Transforming Silicon Photonic Integrated Circuits into Photonic Devices. *Applied Sciences* **2016**, *6*, 426.
86. Lee, J.S.; Carroll, L.; Scarcella, C.; Pavarelli, N.; Menezo, S.; Bernabé, S.; Temporiti, E.; Brien, P.O. Meeting the Electrical, Optical, and Thermal Design Challenges of Photonic-Packaging. *Ieee J Sel Top Quant* **2016**, *22*, 409-417, doi:10.1109/JSTQE.2016.2543150.
87. Parnika, G.; Amit, T.; Xiuyun, H.; Kamil, G.; Kafil, M.R.; Padraic, E.M.; Peter, O.B. Substrate integrated micro-thermoelectric coolers in glass substrate for next-generation photonic packages. *Journal of Optical Microsystems* **2024**, *4*, 011006, doi:10.1117/1.JOM.4.1.011006.
88. Misiakos, K.; Makarona, E.; Hoekman, M.; Fyrogenis, R.; Tukkiniemi, K.; Jobst, G.; Petrou, P.S.; Kakabakos, S.E.; Salapatas, A.; Goustouridis, D.; et al. All-Silicon Spectrally Resolved Interferometric Circuit for Multiplexed Diagnostics: A Monolithic Lab-on-a-Chip Integrating All Active and Passive Components. *ACS Photonics* **2019**, *6*, 1694-1705, doi:10.1021/acsphotonics.9b00235.
89. Zhang, W.; Li, Y.; Jin, B.; Ren, F.; Wang, H.; Dai, W. A Fiber Bragg Grating Interrogation System with Self-Adaption Threshold Peak Detection Algorithm. *Sensors* **2018**, *18*, 1140.
90. Jean-Baptiste, Q.; Didier, P.; David, B.; Karim, H.; Guillaume, L. Experimental study of a tunable hybrid III-V-on-silicon laser for spectral characterization of fiber Bragg grating sensors. In Proceedings of the Proc.SPIE, 2022; p. 1214105.
91. Marin, Y.E.; Nannipieri, T.; Oton, C.J.; Pasquale, F.D. Current Status and Future Trends of Photonic-Integrated FBG Interrogators. *J Lightwave Technol* **2018**, *36*, 946-953, doi:10.1109/JLT.2017.2779848.
92. Marin, Y.E.; Nannipieri, T.; Oton, C.J.; Pasquale, F.D. Integrated FBG Sensors Interrogation Using Active Phase Demodulation on a Silicon Photonic Platform. *J Lightwave Technol* **2017**, *35*, 3374-3379, doi:10.1109/JLT.2016.2598395.
93. Elaskar, J.; Bontempi, F.; Velha, P.; Ayaz, R.M.A.; Tozzetti, L.; Faralli, S.; Pasquale, F.D.; Oton, C.J. Ultracompact Microinterferometer-Based Fiber Bragg Grating Interrogator on a Silicon Chip. *J Lightwave Technol* **2023**, *41*, 4397-4404, doi:10.1109/JLT.2023.3243981.
94. Li, H.; An, Z.; Zhang, S.; Zuo, S.; Zhu, W.; Zhang, S.; Huang, B.; Cao, L.; Zhang, C.; Zhang, Z.; et al. Fully Photonic Integrated Wearable Optical Interrogator. *ACS Photonics* **2021**, *8*, 3607-3618, doi:10.1021/acsphotonics.1c01236.
95. Li, K.; Yuan, P.; Lu, L.; Dong, M.; Zhu, L. PLC-Based Arrayed Waveguide Grating Design for Fiber Bragg Grating Interrogation System. *Nanomaterials* **2022**, *12*, doi:10.3390/nano12172938.
96. Jeffrey, M.R.; Daniel, K.; Ian, J.B.; Shankararaman, R.; Craig, M.L.; Bryan, G.M.; Vincent, S. Dual-control technique for temperature stabilization and tunability of narrowband fiber Bragg gratings. In Proceedings of the Proc.SPIE, 2023; p. 1241317.
97. Rosolem, J.B.; Argentato, M.C.; Bassan, F.R.; Penze, R.S.; Floridia, C.; Silva, A.d.A.; Vasconcelos, D.; Ramos Junior, M.A. Demonstration of a Filterless, Multi-Point, and Temperature-Independent Fiber Bragg Grating Dynamical Demodulator Using Pulse-Width Modulation. *Sensors* **2020**, *20*, 5825.
98. Cao, Z.; Liang, X.; Deng, Y.; Zha, X.; Zhu, R.; Leng, J. Novel Semi-Analytical Solutions for the Transient Behaviors of Functionally Graded Material Plates in the Thermal Environment. *Materials* **2019**, *12*, 4084.

99. Emanuele, B.; Matteo, C.; Massimo, R. High stiffness, high damping chiral metamaterial assemblies for low-frequency applications. In Proceedings of the Proc.SPIE, 2013; p. 86952K.
100. Liu, Y.; Liu, Z.; Huang, A.; Wang, J.; Xin, C. Theoretical modeling and simulation of fiber Bragg grating sensor interrogator based on linear variable filter. *Opt Express* **2023**, *31*, 5777-5793, doi:10.1364/OE.475654.
101. Zhaoyi, L.; Yi, L.; Anyi, H. Errors modeling of fiber Bragg grating sensor interrogator with linear variable filter. In Proceedings of the Proc.SPIE, 2023; p. 126140H.
102. Li, H.; Ma, X.; Cui, B.; Wang, Y.; Zhang, C.; Zhao, J.; Zhang, Z.; Tang, C.; Li, E. Chip-scale demonstration of hybrid III–V/silicon photonic integration for an FBG interrogator. *Optica* **2017**, *4*, 692-700, doi:10.1364/OPTICA.4.000692.
103. Zhuang, Y.; Zou, J.; Zhang, J.; Zhang, L.; Zhang, J.; Meng, L.; Yang, Q. On-Chip Sub-Picometer Continuous Wavelength Fiber-Bragg-Grating Interrogator. *Photonic Sensors* **2024**, *14*, 240126, doi:10.1007/s13320-023-0694-9.
104. Fernández, M.P.; Bulus Rossini, L.A.; Cruz, J.L.; Andrés, M.V.; Costanzo Caso, P.A. High-speed and high-resolution interrogation of FBG sensors using wavelength-to-time mapping and Gaussian filters. *Opt Express* **2019**, *27*, 36815-36823, doi:10.1364/OE.27.036815.
105. Marrazzo, V.R.; Fienga, F.; Riccio, M.; Irace, A.; Breglio, G. Multichannel Approach for Arrayed Waveguide Grating-Based FBG Interrogation Systems. *Sensors* **2021**, *21*, 6214.
106. Przemyslaw, F.; Qi, S.; Tom, V.; Timothy, L.; David, B.P.; Gilberto, B.; Martynas, B. Low-cost fiber Bragg grating interrogation with a femtosecond laser written scattering chip. In Proceedings of the Proc.SPIE, 2023; p. 1240806.
107. Li, K.; Yuan, P.; Lu, L.; Dong, M.; Zhu, L. PLC-Based Arrayed Waveguide Grating Design for Fiber Bragg Grating Interrogation System. *Nanomaterials* **2022**, *12*, 2938.
108. Trita, A.; Vickers, G.; Mayordomo, I.; Thourhout, D.v.; Vermeiren, J. Design, integration, and testing of a compact FBG interrogator, based on an AWG spectrometer. In Proceedings of the Proc.SPIE, 2014; p. 91330D.
109. Xu, H.; Qin, Y.; Hu, G.; Tsang, H.K. Breaking the resolution-bandwidth limit of chip-scale spectrometry by harnessing a dispersion-engineered photonic molecule. *Light: Science & Applications* **2023**, *12*, 64, doi:10.1038/s41377-023-01102-9.
110. Zhang, Z.; Song, Q.; Xiao, S.; Xu, K. Single-Shot on-Chip Diffractive Speckle Spectrometer with High Spectral Channel Density. *Laser Photonics Rev* **2025**, *n/a*, 2401987, doi:https://doi.org/10.1002/lpor.202401987.
111. He, P.; Du, T.; Zhao, K.; Dong, J.; Liang, Y.; Zhang, Q. Lightweight 3D Graphene Metamaterials with Tunable Negative Thermal Expansion. *Adv Mater* **2023**, *35*, 2208562, doi:https://doi.org/10.1002/adma.202208562.
112. Prechtl, M.; Parhizkar, S.; Hartwig, O.; Lee, K.; Biba, J.; Stimpel-Lindner, T.; Gity, F.; Schels, A.; Bolten, J.; Suckow, S.; et al. Hybrid Devices by Selective and Conformal Deposition of PtSe2 at Low Temperatures. *Adv Funct Mater* **2021**, *31*, 2103936, doi:https://doi.org/10.1002/adfm.202103936.
113. Niu, W.; Cao, X.; Wang, Y.; Yao, B.; Zhao, Y.; Cheng, J.; Wu, S.; Zhang, S.; He, X. Photonic Vitrimer Elastomer with Self-Healing, High Toughness, Mechanochromism, and Excellent Durability based on Dynamic Covalent Bond. *Adv Funct Mater* **2021**, *31*, 2009017, doi:https://doi.org/10.1002/adfm.202009017.
114. Falak, P.; Lee, T.; Zahertar, S.; Shi, B.; Moog, B.; Brambilla, G.; Holmes, C.; Beresna, M. Compact high-resolution FBG strain interrogator based on laser-written 3D scattering structure in flat optical fiber. *Scientific Reports* **2023**, *13*, 8805, doi:10.1038/s41598-023-35708-1.
115. Rudloff, G.; Soto, M.A. Multipeak Wavelength Detection of Spectrally Overlapped Fiber Bragg Grating Sensors Through a CNN-Based Autoencoder. *Ieee Sens J* **2024**, *24*, 20674-20687, doi:10.1109/JSEN.2024.3400819.
116. Tian, W.; Bas, B.; Harmsen, D.; Williams, K.; Leijtens, X. Temperature Sensing Diode in InP-Based Photonic Integration Technology. *Ieee Photonics J* **2024**, *16*, 1-8, doi:10.1109/JPHOT.2024.3374266.
117. Hendricks, J.; Ahmed, Z.; Barker, D.; Douglass, K.; Eckel, S.; Fedchak, J.; Klimov, N.; Ricker, J.; Scherschligt, J. Quantum-Based Photonic Sensors for Pressure, Vacuum, and Temperature Measurements: A Vison of the Future with NIST on a Chip. *Measurement. Sensors* **2021**, *7*, 10.5162/SMSI2021/PT5167.

 doi:10.20944/preprints202503.0993.v1




118. Toet, P.; Hagen, R.A.; Hakkesteegt, H.; Lugtenburg, J.; Maniscalco, M. Miniature and low cost fiber Bragg grating interrogator for structural monitoring in nano-satellites. In Proceedings of the International Conference on Space Optics — ICSO 2014, Tenerife, Canary Islands, Spain, Oct 6-10, 2017.
119. Shaker, L.M.; Al-Amiery, A.; Isahak, W.N.R.W.; Al-Azzawi, W.K. Integrated photonics: bridging the gap between optics and electronics for enhancing information processing. *Journal of Optics* **2023**, doi:10.1007/s12596-023-01321-8.
120. Lihachev, G.; Riemensberger, J.; Weng, W.; Liu, J.; Tian, H.; Siddharth, A.; Snigirev, V.; Shadymov, V.; Voloshin, A.; Wang, R.N.; et al. Low-noise frequency-agile photonic integrated lasers for coherent ranging. *Nat Commun* **2022**, *13*, 3522, doi:10.1038/s41467-022-30911-6.
121. Mosses, A.; Joe Prathap, P.M. Analysis and codesign of electronic–photonic integrated circuit hardware accelerator for machine learning application. *Journal of Computational Electronics* **2024**, *23*, 94-107, doi:10.1007/s10825-023-02123-8.