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An ultra-fast interrogation method for a weak fiber Bragg grating array using an on-chip integrated DFB laser array

Kaichuan Xu, Feng Wang*, Pan Dai, Chaobo Zhu, Jiacheng Wang, Yuan Liu, Tao Fang and Xiangfei Chen*

Abstract: We propose an ultra-fast interrogation method for a weak fiber Bragg grating (WFBG) array based on a self-designed distributed feedback multi-wavelength laser array (DFB-MLA) chip. The laser integrates eight wavelength channels with a uniform wavelength interval of 0.13 nm, which is precisely controlled using the reconstruction-equivalent-chirp (REC) technique. Each channel is cascaded with a semiconductor optical amplifier (SOA) functioning as an optical shutter (referred to as s-SOA). The outputs of all 8 channels are combined into one waveguide via three Y-junction combiners and are then cascaded with another SOA functioning as an intensity modulator (referred to as m-SOA). The DFB-MLA emits eight wavelengths simultaneously. The s-SOAs cyclically enable the output of these wavelengths, and the m-SOA modulates each output beam into optical pulses. By sequentially injecting these pulses into a WFBG array and detecting the reflected signals, the position and wavelength shift of each WFBG can be accurately determined. In experiments, we achieve 1 MHz demodulation rate for 10 WFBGs, with a wavelength stability of ± 5 pm, which represents one of the highest demodulation capacities reported for WFBG interrogation systems with a compact and low-complexity architecture. This technology enables high-precision, real-time tracking of ultra-high-frequency vibrations using a compact system configuration, opening wide application opportunities in structural health monitoring.

Keywords: ultra-fast interrogation; weak fiber Bragg gratings; DFB-MLA; reconstruction-equivalent-chirp technique

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1 Introduction

High-frequency vibration is an inherent dynamic response of critical structures in aerospace, energy equipment, precision manufacturing, and other fields¹⁻³. The initiation of cracks and the degradation of structural strength are often accompanied by transient high-frequency vibrations and abnormal vibration patterns. Therefore, high-precision and large-dynamic-range vibration measurement is essential for fault diagnosis, lifespan prediction, and structural safety monitoring. Currently, mainstream vibration sensing technologies include piezoelectric accelerometers⁴, laser Doppler vibrometers (LDVs)⁵, and micro-electromechanical systems (MEMS) sensors⁶. Piezoelectric accelerometers can achieve bandwidths up to 15 kHz but are susceptible to electromag-

netic interference. LDVs provide nanometer-scale resolution; however, they are bulky, expensive, and challenging to deploy for online and distributed monitoring. MEMS sensors offer compact size and high sensitivity but are limited in dynamic range. In contrast, fiber Bragg grating (FBG) sensors offer unique advantages such as electromagnetic immunity, corrosion resistance, compact size⁷, making them promising candidates for vibration sensing applications⁸. Nevertheless, conventional FBG interrogation systems are typically limited to kHz-level response bandwidths and narrow measurable dynamic ranges which restrict their applicability in ultra-high-frequency and large-amplitude vibration monitoring scenarios.

Traditional FBG sensors primarily employ broadband light sources, microwave photonics (MWP), or wavelength-swept

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lasers to track Bragg wavelength shifts^{9–11}. Broadband-source-based systems utilize spectrometers or optical spectrum analyzers, whose interrogation speed is fundamentally limited by the acquisition rate, usually below 1 kHz. MWP-based approaches enable high-resolution demodulation by converting wavelength shifts into electrical-domain signals, but they require complex signal processing and bulky instrumentation, such as vector network analyzers, leading to increased system cost and latency. Wavelength-swept lasers, in contrast, are ideal for high-speed real-time FBG interrogation due to their rapid scanning, high resolution, and high signal-to-noise ratio¹². In 2017, Yao et al. demonstrated a 100-kHz interrogation system for 10 identical weak FBGs (WFBGs) using a DFB swept laser and time-division multiplexing (TDM)¹³. However, a minimum spatial interval of 100 m between sensors was required to avoid overlap of the reflection spectra, due to the limited wavelength sweep speed. To increase sensing points, researchers have proposed a hybrid time-wavelength division multiplexing (TWDM) technique that integrates TDM and wavelength-division multiplexing (WDM). In 2018, Wang et al. implemented a Fourier domain mode-locked (FDML) laser for high-speed WFBG interrogation¹⁴, generating swept-wavelength pulses with 5 μ s duration, 100 kHz repetition rate, and 18 nm spectral range. These properties enable achieving a capacity of 200 uniquely encoded WFBGs with 5 m spatial resolution at 100 kHz. In 2025, Xu et al. developed a fast tunable laser source of 40 nm spectral range for large-capacity ultra-weak fiber Bragg gratings (UW-FBGs) interrogation. By employing the TWDM method, they demodulate 50 UW-FBGs at a 5 kHz frequency and a spatial resolution of 0.4 m¹⁵.

Despite these advances, the sampling rate limitation of the conventional FBG interrogation system is mainly due to two reasons. First, the wavelength scanning speed is limited by the laser or the filter. Second, the WDM method for multi-point sensing requires a wide spectral range. To address these limitations and enable extreme sensing applications, this work proposes an ultra-fast interrogation scheme for a WFBG array based on a chip-integrated wavelength-switching DFB-MLA. Unlike traditional continuous wavelength scanning methods, the laser chip rapidly switches among multiple channels at nanosecond-scale speed, with an on-chip switched s-SOA enabling MHz-level demodulation. By combining the REC-based DFB-MLA^{16–17} with a TDM strategy, rapid and deterministic wavelength switching is achieved without mechanical tuning elements.

As summarized in Table 1, a comprehensive comparison with representative vibration sensing technologies demonstrates that the proposed system offers clear advantages in demodulation rate and sensing capacity. These features render it highly suitable for extreme dynamic sensing scenarios, such as spacecraft launch vibration monitoring, impact response detection in high-speed rail systems, real-time monitoring of wind turbine blades under extreme wind loads, and shock or blast measurements in industrial and

defense environments. The organization of this paper is as follows. The demodulation principle, simulation verification, and chip design are presented in Sections 2 and 3. Wavelength calibration and system stability verification are described in Section 4. The demodulation system, static measurements, and high-frequency vibration monitoring experiments are detailed in Section 5. System limitations and scalability are discussed in Section 6. Finally, conclusions are drawn in Section 7.

Table 1 | Comparison of vibration sensing performance

Technology	Demodulation rate	Sensing capacity
Piezoelectric accelerometer ⁴	15 kHz	Single-point
Laser doppler vibrometer (LDV) ⁵	22 kHz	Single-point
MEMS sensors ⁶	16 kHz	Single-point
FBG (Broadband source) ⁹	< 1 kHz	3 FBGs
FBG (Microwave photonics) ¹⁰	40 kHz	105 WFBGs
WFBG (DFB Laser) ¹³	100 kHz	10 WFBGs
WFBG(FDML laser) ¹⁴	100 kHz	200 WFBGs
UW-FBG(DFB-MLA laser) ¹⁵	5 kHz	50 UW-FBGs
This work	1 MHz	10 WFBGs

2 Design and simulation of WFBG demodulation

In a WFBG array sensing system based on the TDM method¹⁸, all gratings have the same central wavelength and are inscribed at equal intervals along a fiber, as shown in Fig. 1. Since the reflected signals from different WFBGs return back to the avalanche photodiode (APD) at different times, each WFBG in the array can be located according to the principle of optical time-domain reflectometry (OTDR). Assuming that the round-trip time of the reflected signal from the i -th WFBG is τ_i , it can be expressed as

$$\tau_i = \frac{2n_{\text{eff}}L_i}{c} \quad (1)$$

$$\Delta t = \tau_{(i+1)} - \tau_i, \quad (2)$$

where L_i is the distance of the i -th WFBG from the APD. n_{eff} is the effective refractive index of the fiber, and c is the speed of light in vacuum. Δt represents the time difference between reflections of the same optical pulse from adjacent WFBGs.

For each complete measurement, the pulsed laser emits N optical pulses with different central wavelengths ($\lambda_1, \lambda_2, \dots, \lambda_N$) into the WFBG array composed of n WFBGs. The launching period τ of the optical pulse should be larger than the round-trip time of the lightwave in the WFBG array to avoid signal overlap. Therefore, a complete measurement period is given by $T = N\tau$. The typical sampled reflection spectrum waveforms are shown in Fig. 1. By applying

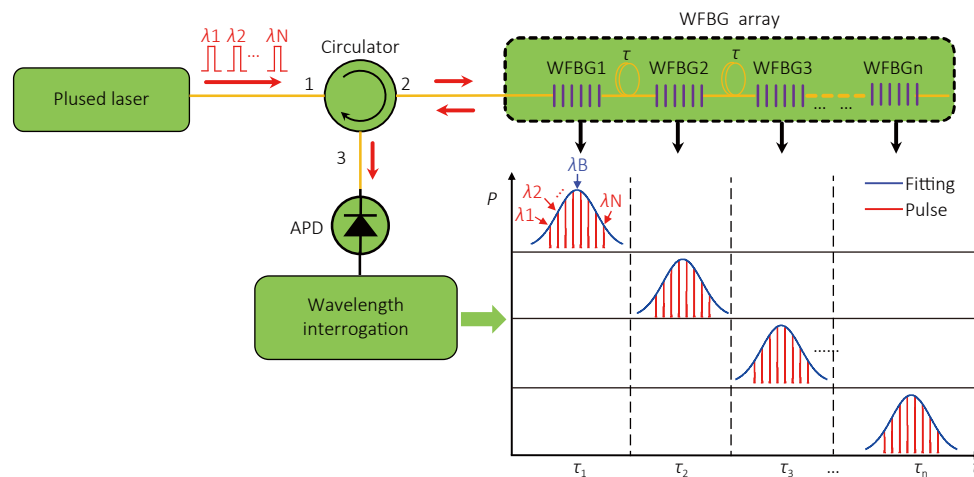


Fig. 1 | TDM interrogation principle of a WFBG array.

Gaussian fitting to the sampled reflection pulses, the central wavelength of each WFBG can be demodulated. When the WFBGs are subjected to environmental factors such as temperature, strain, or vibration, their central wavelengths shift accordingly. The Bragg wavelength shift $\Delta\lambda_B$ can be determined by the following equation¹⁹

$$\Delta\lambda_B = \lambda_B \times (1 - p_e) \times \varepsilon, \quad (3)$$

where λ_B is the initial Bragg wavelength, p_e is the effective photoelastic coefficient, and ε is the strain. Therefore, the vibration of WFBG can be monitored from the wavelength shift.

Several critical considerations must be addressed for the proposed WFBG demodulation system. First, the DFB-MLA chip should cover a reasonable spectrum range to ensure that the system's strain measurement range is adequate. Second, the wavelength interval ($\Delta\lambda$) between adjacent laser channels should properly sample the WFBG reflection spectrum so that the Bragg center wavelength can be accurately reconstructed through Gaussian fitting. These requirements introduce a trade-off among the number of laser channels, the channel's wavelength interval, and the full width at half maximum (FWHM) of the WFBG reflection spectrum. To quantitatively evaluate these effects and optimize the system parameters, a series of numerical simulations were carried out. In the simulations, the reflection spectrum of a WFBG is modeled as a Gaussian function with a predefined center wavelength (1536.5 nm) and the FWHM. Discrete sampling points are generated by evaluating this ideal spectrum at the specific emission wavelengths of the DFB-MLA, which are uniformly distributed with a fixed interval ($\Delta\lambda$). To emulate practical system imperfections, random power fluctuations (e.g., $\pm 4\%$) are introduced to each sampling point. Gaussian fitting is then applied to these noisy discrete points to extract the center wavelength. The demodulation error is defined as the maximum difference between the fitted center and the ideal one. These results represent the statistical outcomes

from 1000 simulations.

To evaluate the influence of the number of laser channels, the first simulation was performed with a wavelength interval $\Delta\lambda$ of 0.2 nm and a WFBG reflection spectrum with a FWHM of 1.2 nm. The number of laser channels was configured as 4, 6, 8, and 10. In each simulation, Gaussian fitting was applied to the discretely sampled reflection data, and the fitted central wavelength was compared with the ideal WFBG center wavelength. The average fitting error is summarized in Fig. 2. It can be observed that the fitting errors for 4 and 6 sampling points are relatively large, whereas those for 8 and 10 sampling points are comparable, both around 6.5 pm. These results demonstrate that the fitting error decreases nonlinearly with increasing sampling points and becomes saturated when the number of laser channels exceeds eight.

A second simulation was conducted to investigate the effect of wavelength interval on demodulation accuracy. The wavelength intervals and corresponding FWHMs of the WFBG reflection spectra are listed in Table 2. In all cases, the wavelength coverage of the laser chip exceeds the FWHM by 200 pm to ensure that there are at least six sampling points fall within the FWHM region. Under the assumption of a strain-wavelength sensitivity of 1 $\mu\text{e}/\text{pm}$. Figure 3 presents the simulation results for randomly selected wavelength intervals of 0.1 nm, 0.3 nm, 0.5 nm, and 0.7 nm. For each interval, 1000 simulations were performed, and the maximum difference between Gaussian-fitted centers and the ideal WFBG center are shown in Table 2. The results, illustrated in Fig. 3, show that larger wavelength intervals lead to increased fitting errors. In the proposed wavelength-switching interrogation scheme, both the number of laser channels and the wavelength spacing jointly determine the achievable demodulation speed and fitting accuracy. Increasing the number of channels reduces the effective interrogation rate due to sequential wavelength switching and increases system complexity as well as sensitivity to inter-channel power imbalance and noise, while

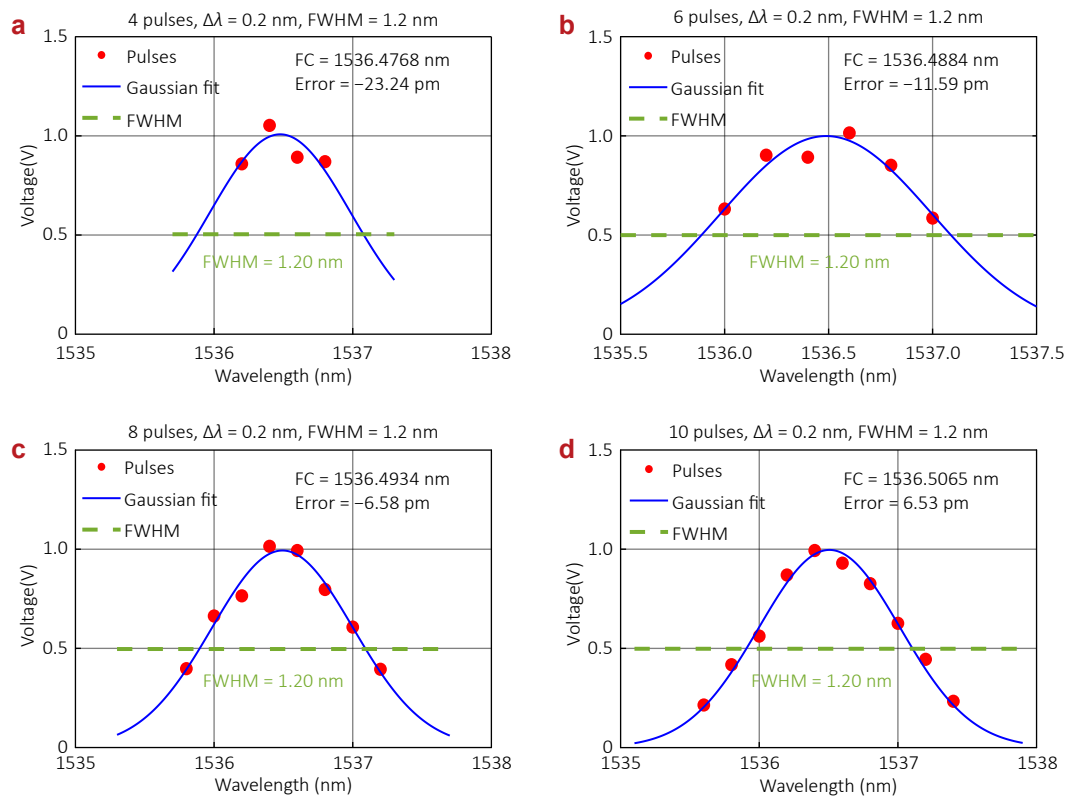


Fig. 2 | Gaussian fitting results for different numbers of sampling points ($\Delta\lambda = 0.2$ nm, FWHM = 1.2 nm).

smaller wavelength spacing improves fitting accuracy at the expense of stricter wavelength control requirements. Moreover, since the DFB-MLA must be progressively combined through cascaded Y-type combiner, the number of laser channels is constrained to 2^n (n is an integer). Considering this device-level constraint together with simulation results and system requirements, an 8-channel (2^3) DFB-MLA with a wavelength spacing of 0.13 nm, covering a total wavelength range of approximately 0.90 nm, is selected to achieve a balanced performance in terms of demodulation speed, accuracy, and system robustness. All the FWHMs of the WFBGs' reflective spectra are about 0.7 nm. The REC technique^{20–22} is employed to realize the proposed 8-channel DFB-MLA, enabling ultra-high-speed demodulation.

Table 2 | Wavelength intervals, FWHM, and fitting errors.

$\Delta\lambda$ (nm)	FWHM (nm)	Error (pm)
0.1	0.5	2.35~1.94
0.2	1.2	-7.25~6.55
0.3	1.9	-12.78~11.97
0.4	2.6	-16.82~16.88
0.5	3.3	-21.35~20.78
0.6	4.0	-27.58~25.25
0.7	4.7	-31.88~30.70
0.8	5.4	-36.54~37.53

3 Realization of the DFB-MLA

Traditional tunable sources often suffer from limited wavelength-scanning speed, which makes them incapable of high-frequency vibration monitoring.

Thus, we have departed from the continuously wavelength-sweeping scheme, developing a wavelength-switching laser source. In this scheme, eight wavelength channels are monolithically integrated in a parallel way, and each channel is cascaded with a SOA acting as a shutter (s-SOA) to sequentially switch different wavelength channels. The multiple wavelength channels are combined together via three-stage Y-combiner waveguide, and then are cascaded with a master SOA acting as an intensity modulator (m-SOA). The schematic diagram of the photonic chip is shown in Fig. 4(a), and the microscope image of the photonic chip is shown in Fig. 4(b).

The precise wavelength control of the eight wavelength channels is essential for achieving uniformly accurate sensing in the whole working wavelength range. Thus, we employ the REC technique to fabricate the grating structure in each wavelength channel^{23,24}. In the REC process, a highly uniform seed grating is first fabricated using holographic lithography. Because a π laser's waveguide can significantly improve the single-mode characteristic, a resampling sub-grating is fabricated with lithography to form a π phase shift. By adjusting the sampling period, the wavelength of each

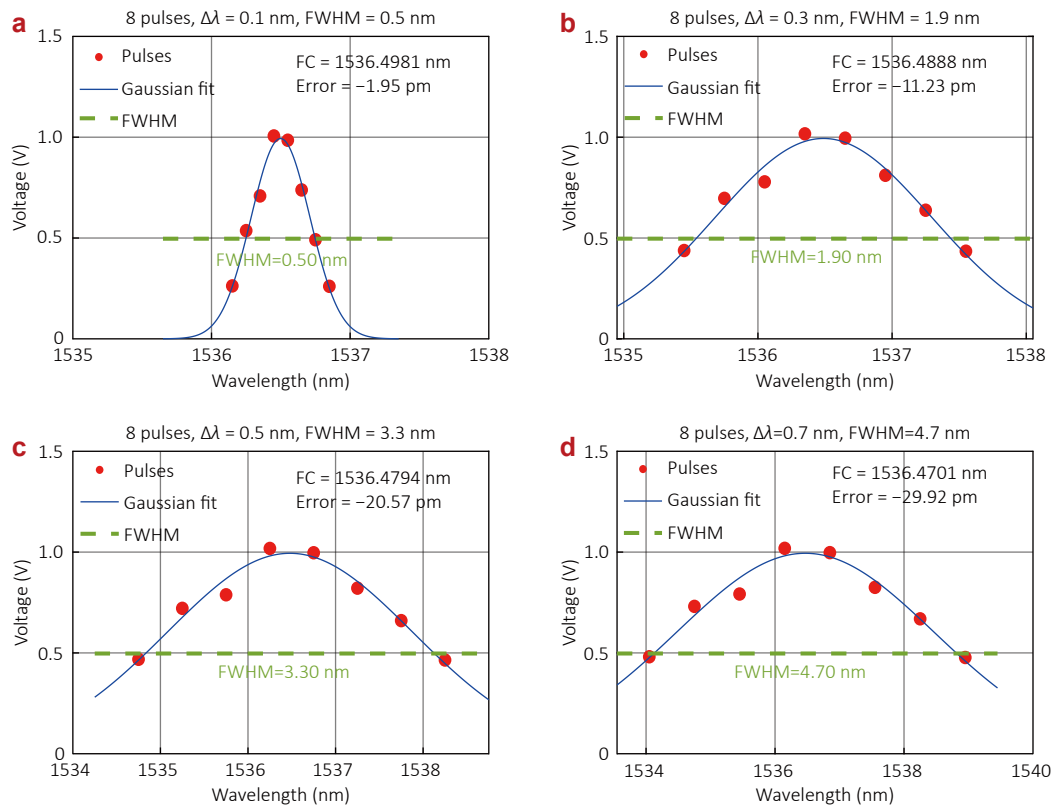


Fig. 3 | Gaussian fitting results for different wavelength intervals and FWHMs. (a) $\Delta\lambda = 0.1$ nm, FWHM = 0.5 nm; (b) $\Delta\lambda = 0.3$ nm, FWHM = 1.9 nm; (c) $\Delta\lambda = 0.5$ nm, FWHM = 3.3 nm; (d) $\Delta\lambda = 0.7$ nm, FWHM = 4.7 nm.

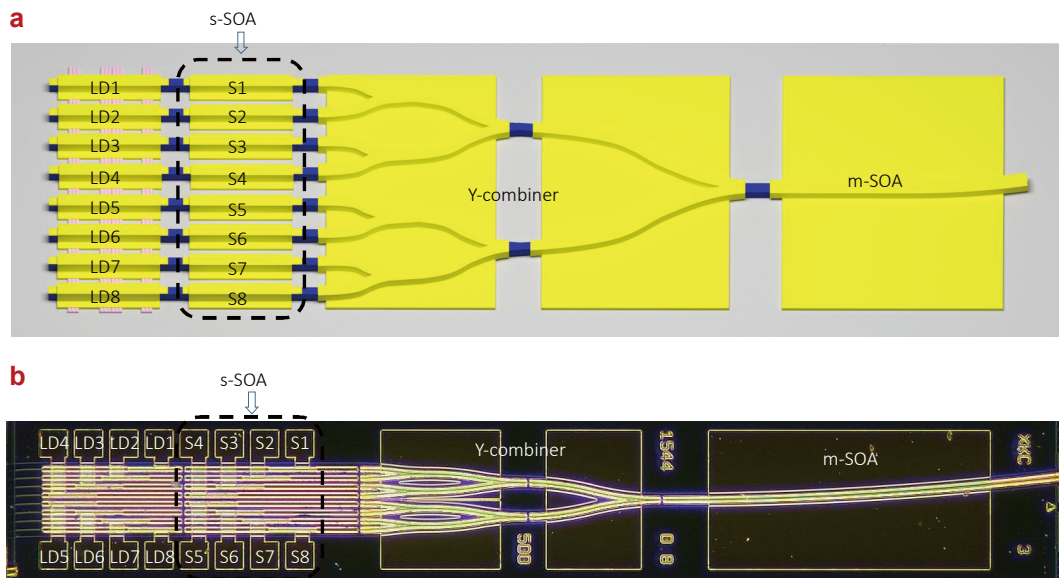


Fig. 4 | (a) Schematic diagram of the photonic chip. (b) Microscope image of the photonic chip.

laser cavity can be precisely selected. In the C-band, the width of the sampled gratings is typically on the order of a few μm . Since the central wavelength is predominantly determined by the sampling period rather than the fine phase accuracy of the sub-grating, REC effectively

suppresses the impact of higher-order sub-grating phase errors. As a result, it provides stable and well-controlled multi-wavelength output across all channels. This design achieves accurate multi-wavelength output. The principle of the REC technique is illustrated in Fig. 5.

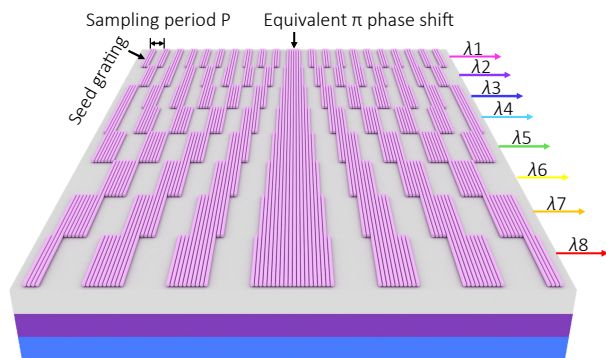


Fig. 5 | Grating structure for different lasing wavelengths based on the REC technical.

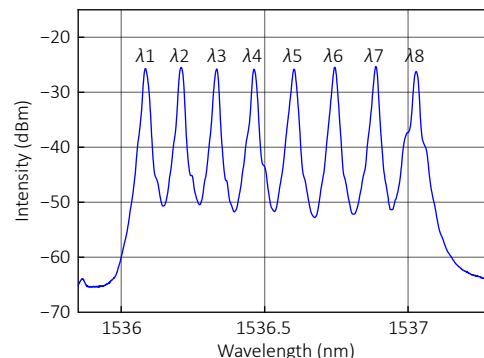


Fig. 7 | Typical spectrum of the 8-channel DFB-MLA.

4 Wavelength calibration and stability results

Precise wavelength calibration and stability testing are crucial for ensuring the accuracy and reliability of the interrogation system. The experimental setup, shown in Fig. 6, is implemented to perform wavelength calibration and stability evaluation of the eight channels (λ_1 – λ_8). The DFB-MLA output is split by a 10:90 optical coupler, with 10% directed to a high-resolution optical spectrum analyzer (OSA) for wavelength calibration and 90% sent to a photodetector (PD) for stability testing via an oscilloscope (OSC).

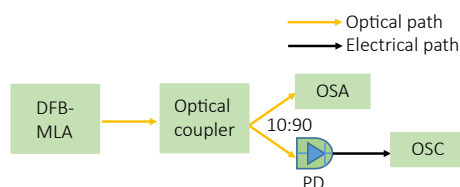


Fig. 6 | System diagram for wavelength calibration and stability testing.

As shown in Fig. 7, under constant driving current and temperature conditions, the center wavelengths of the eight channels are continuously monitored for one hour using an OSA with a resolution of 0.02 nm. To further assess the temporal stability of the wavelengths, 2000 complete cycles of the eight pulses with different wavelengths are continuously recorded.

The results indicate that the DFB-MLA chip operates over a wavelength range of approximately 0.95 nm (1536.08 nm–1537.03 nm), with the center wavelength of each channel summarized in Table 3 and channel spacings ranging from 0.125 nm to 0.146 nm. Stability analysis shows that the maximum peak power fluctuations of each channel, illustrated in Fig. 8 and listed in Table 3, range from 3.66% to 4.69%, demonstrating excellent wavelength stability and repeatability for high-precision sensing applications.

Table 3 | Wavelength calibration and repeatability

Channel	λ_i (nm)	Maximum peak fluctuation
λ_1	1536.083	3.91%
λ_2	1536.208	4.12%
λ_3	1536.337	3.85%
λ_4	1536.469	4.08%
λ_5	1536.608	4.32%
λ_6	1536.746	3.95%
λ_7	1536.885	4.69%
λ_8	1537.031	3.66%

5 Experimental setup and results

5.1 Experimental setup

Following validation of the DFB-MLA's wavelength calibration and stability, a WFBG array interrogation system is implemented as depicted in Fig. 9. The pulsed light output from the DFB-MLA is split into two paths via a 10:90 optical coupler (OC). The 90% output is used for sensing. The beam of this path propagates through port 1 of the optical circulator, exiting from port 2 into the WFBG array. Reflected signals from the WFBG array are collected from the circulator's port 3 and received by an APD. Then, the photoelectric signal is recorded by the OSC for subsequent processing, which can convert the captured time-domain reflection signal into the frequency domain.

The 10% path is a monitoring path to track the pulse power via a PD in real time. During subsequent data processing, the reflected signal is normalized by dividing the monitoring signal. This procedure reduces errors caused by uneven input power, enabling more accurate wavelength extraction. Crucially, FPGA-generated trigger (Trig) signals synchronize the OSC to unambiguously identify and segment individual operational cycles. In this system, each pulse has a width of 10 ns and the time interval to the next pulse is 120 ns. A full interrogation cycle consists of 8 pulses with different wavelengths, resulting in a total cycle

duration of 960 ns, which corresponds to an effective sampling rate of approximately 1 MHz.

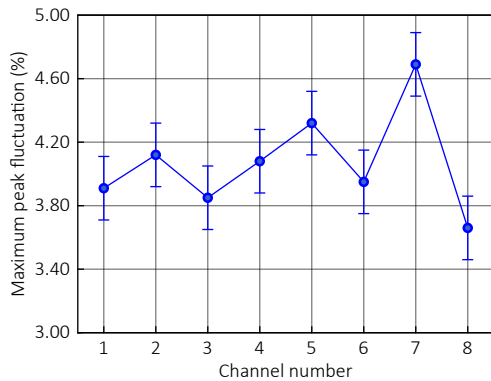


Fig. 8 | Stability analysis: maximum peak fluctuation of the eight channels.

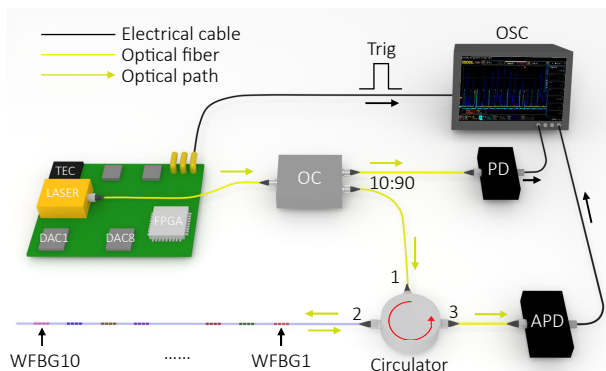


Fig. 9 | Schematic of the WFBG array interrogation system.

5.2 Experimental results

To demonstrate the feasibility of the proposed interrogation scheme, ten WFBGs are cascaded in the fiber. All the WFBGs have the same central wavelength of 1536.50 nm, ~3% reflectivity, and 1.2 nm FWHM. The spatial interval between adjacent WFBG is 1 m. The obtained time-domain signal is illustrated in Fig. 10. Figure 10(a) shows the overall signal for a complete measurement, and Fig. 10(b) is the enlargement of the dashed rectangle part of Fig. 10(a). Taking the pulse light with wavelength of λ_6 as an example, when it is injected into the WFBG array, ten reflected pulses, labeled from 1 to 10, are generated at the corresponding WFBGs' positions, as shown in Fig. 10(b).

Although the input optical pulse is only 10 ns wide, slight wavelength variations occur within a single pulse due to modulation-current-induced temperature fluctuations. Consequently, variations in the WFBG reflection spectra lead to different reflected intensities, and some signals exhibit double peaks or slight temporal distortions. Instead

of relying on a single peak, the proposed method averages the reflected signal over the 10 ns pulse duration, enabling stable and accurate Bragg wavelength reconstruction with negligible influence from secondary peaks. By aligning and extracting the reflected pulses with the same indices generated by different input wavelengths, the reflection spectrum corresponding to each individual WFBG can be reconstructed.

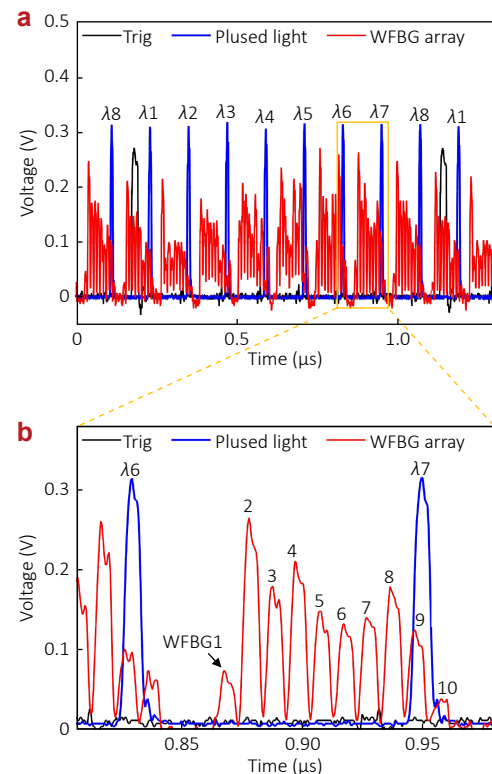


Fig. 10 | Verification of the TDM-based interrogation system. (a) Reflected signals from 10 WFBGs at different wavelengths. (b) Enlarged view of the dashed rectangle in (a).

As a representative case, Fig. 11 shows the response of WFBG1 to the sequentially injected eight different wavelength pulses. The corresponding reflected signals (red curve) exhibit eight sampling peaks that align sequentially according to different wavelengths. By applying Gaussian fitting to these peaks (pink dashed line), the central wavelength of WFBG1 is successfully demodulated.

To further evaluate the long-term performance of the proposed demodulation scheme, Fig. 12 presents 10,000 measurement results of WFBG1. The results show that the central wavelength consistently remains within the range of $1536.450 \text{ nm} \pm 0.005 \text{ nm}$, demonstrating excellent temporal stability.

Subsequently, a vibration sensing experiment is conducted to evaluate the dynamic response performance of

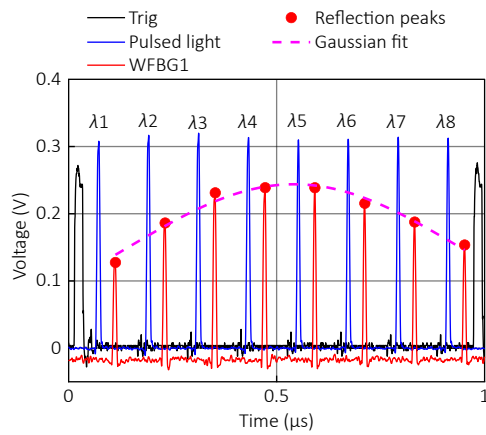


Fig. 11 | WFBG1 reflection spectra under eight wavelength-multiplexed pulses and Gaussian-fitted peak curves.

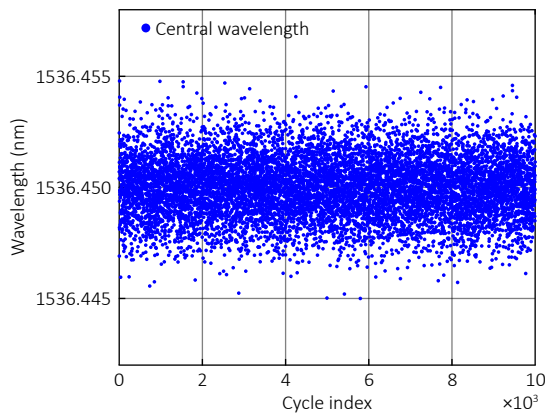


Fig. 12 | Demodulation results of 10,000 cycles under static conditions.

the proposed interrogation system. WFBG1 is mounted on a vibration exciter driven by an arbitrary waveform generator and powered by a signal amplifier to produce precisely controlled mechanical vibrations. The 1 kHz sinusoidal excitation is applied on WFBG1. Figure 13(a) displays the time-domain waveform of the demodulated vibration signal. Fig. 13(b) shows the corresponding power spectral density (PSD). The results exhibit high consistency between the demodulated and applied excitation frequencies confirming the system's excellent frequency resolution and stability.

To further evaluate the performance of the proposed demodulation system under high-frequency and large-amplitude vibration conditions, the WFBG1 sensor was mounted at the free end of a custom metal cantilever beam, and large-amplitude vibrations were induced by applying a manual transient impact. Figure 14(a) shows the demodulated time-domain response, exhibiting a typical decaying oscillatory waveform, while Fig. 14(b) presents the corresponding frequency-domain results obtained via Fast Fourier Transform (FFT). The experimental results demonstrate that the system can reliably capture dynamic strain with a peak amplitude of approximately 350 $\mu\epsilon$ and accu-

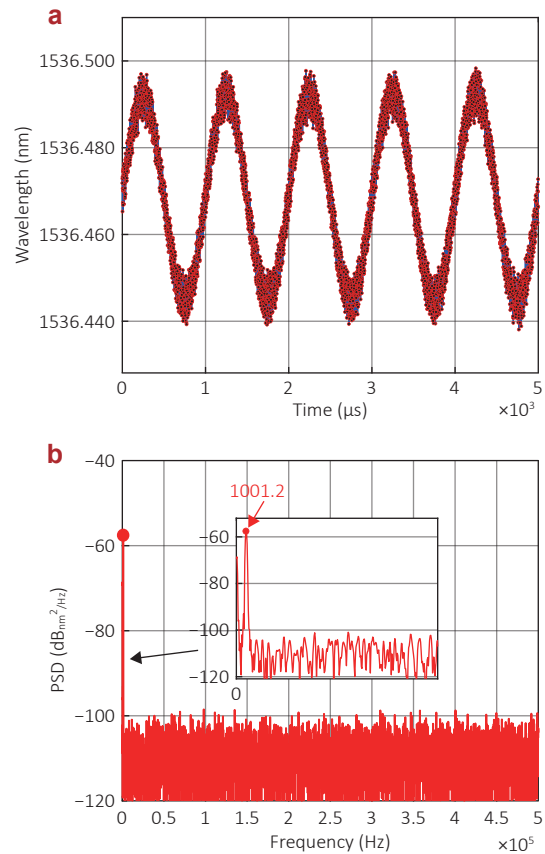


Fig. 13 | Interrogation results of the vibration experiment: (a) time-domain signal; (b) PSD.

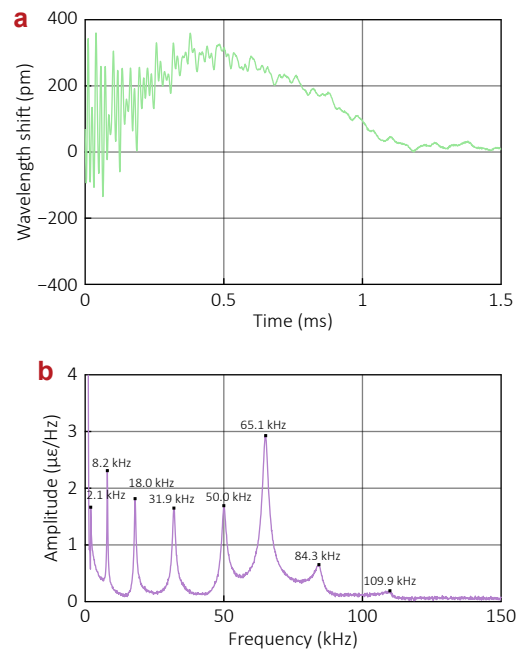


Fig. 14 | Interrogation results of the vibration experiment: (a) time-domain response of the WFBG1 sensor; (b) frequency-domain spectrum obtained from FFT analysis.

rately resolve a dominant vibration frequency of 65.1 kHz in the frequency domain, indicating robust dynamic tracking capability and high-frequency resolution under large-amplitude excitation. Benefiting from the rapid wavelength-switching mechanism, the system enables real-time monitoring of dynamic strain variations and precise extraction of vibration features through spectral analysis. These results further highlight the strong potential of the proposed demodulation system for applications demanding high-frequency response and wide dynamic range, such as mechanical vibration monitoring, structural health assessment, and fault diagnosis.

6 Discussion

The maximum switching rate of our DFB-MLA is primarily limited by the on-chip s-SOAs. Their physical mechanisms, particularly the carrier lifetime, set the fundamental speed constraint. The carrier lifetime in the SOA active region determines the intrinsic gain recovery time, which typically lies in the sub-nanosecond to few-nanosecond range for InP-based SOAs, thereby setting the fundamental physical limit on the wavelength switching speed. In practice, the achievable switching rate is further influenced by the characteristics of the driving circuitry, including the current settling time and the parasitic capacitance introduced by the s-SOA electrodes. In contrast, thermal transients induced by current modulation occur on much longer timescales (typically μs to ms) and therefore do not limit the nanosecond-scale wavelength switching process.

From the perspectives of detection and signal processing, neither the APD bandwidth nor the adopted signal processing scheme constitutes a dominant limitation of the current system speed. The APD used in this work provides sufficient bandwidth to clearly capture nanosecond-scale optical pulses at a 1 MHz interrogation rate, with the photodetection and electronic readout chain operating well below its bandwidth limit. Meanwhile, the signal extraction relies on time-domain averaging of the reflected pulses, which features low computational complexity, strong robustness, and is well suited for real-time implementation. As a result, in the present system, the detection and signal processing stages do not impose a practical constraint on the overall interrogation speed.

7 Conclusion

This study develops an eight-channel chip-integrated DFB-MLA chip based on an original REC technology, establishing an ultra-fast demodulation system for a WFBG array. The system achieves a maximum demodulation rate of 1 MHz with a wavelength error within ± 5 pm over 10,000 cycles, demonstrating high precision and long-term stability. It accurately captures high-frequency, large-amplitude vibrations, measuring signals up to 65.1 kHz with a peak strain of 350 $\mu\epsilon$. By employing TDM technology, multiple

WFBGs can be demodulated simultaneously on a single fiber, enhancing efficiency. These features highlight the system's high-speed, high-accuracy performance and its broad potential for structural health monitoring and dynamic sensing applications.

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Author contributions

Kaichuan Xu contributed to the conception and design of the study, system implementation, data acquisition and analysis, and drafted the original manuscript. Feng Wang and Xiangfei Chen supervised the research project and provided critical revisions of the manuscript. Pan Dai and Chaobo Zhu participated in the experimental setup and data analysis. Jiacheng Wang and Yuan Liu contributed to software development and experimental validation. Tao Fang assisted with result interpretation and manuscript revision. All authors have read and agreed to the published version of the manuscript. Each author accepts personal accountability for their own contributions and for ensuring the integrity and accuracy of the work.

Competing interests

The authors declare no competing financial interests.



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