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# Recent Progress in Fiber-Optic Hydrophones

Zhou MENG[1*], Wei CHEN[1], Jianfei WANG[1], Xiaoyang HU[1],
Mo CHEN[1], and Yichi ZHANG[1,2]

[1]*College of Meteorology and Oceanology, National University of Defense Technology, Changsha 410073, China*
[2]*Academy of Artillery and Air Defense, Nanjing 210000, China*

[*]Corresponding author: Zhou MENG E-mail: zhoumeng6806@163.com

**Abstract:** Fiber-optic hydrophone (FOH) is a significant type of acoustic sensor, which can be used in both military and civilian fields such as underwater target detection, oil and natural gas prospecting, and earthquake inspection. The recent progress of FOH is introduced from five aspects, including large-scale FOH array, very-low-frequency detection, fiber-optic vector hydrophone (FOVH), towed linear array, and deep-sea and long-haul transmission. The above five aspects indicate the future development trends in the FOH research field, and they also provide a guideline for the practical applications of FOH as well as its array.

**Keywords:** Fiber-optic hydrophone; large-scale array; very-low-frequency detection; fiber-optic vector hydrophone; towed linear array; deep sea; long-haul fiber transmission

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## 1. Introduction

Fiber-optic hydrophone (FOH) is a new generation of underwater acoustic sensor, which uses fiber as the medium of signal transmission and sensing. It has a variety of advantages such as high sensitivity, large dynamic range, small size, light weight, immunity to electromagnetic interference, and ease to large-scale arrays, so it has attracted wide attention since the first paper about FOH published in 1977 [1]. FOH is significant in both military and civilian fields, including underwater target detection, oil and natural gas prospecting, earthquake inspection. To date, FOH has a great many applications such as seabed fixed array, towed array, flank array, buoy, and subsurface buoy [2]. To be noticed, FOH has many different types which carry on modulation to optical parameters such as intensity, frequency, wavelength, phase, and polarization. Among these types, the phase-modulated one, i.e., the interferometric FOH, has been especially widely used due to its highest sensitivity.

Owing to the huge potential for civilian and military applications, many countries have spent a great deal of efforts on the research and development of FOH since 1977 [3–30], e.g., Naval Research Laboratory (U.S.), QinetiQ (U.K.), and Optoplan (Norway). Although the start of FOH research is a little later in China [31], a series of key techniques have been broken through by some Chinese universities and research institutes since 1990s [32–52], and more attention has been paid to the practical applications of FOH array.

Recently, with the continual reduction of the underwater target radiation noise as well as the

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rising of ocean ambient noise (maritime shipping, seafloor mining, etc.), the detection difficulty of underwater acoustic signal using the FOH array is increasing rapidly. Also, the ocean oil-gas exploitation has extended from continental shelf to the deep sea and the request of stratigraphic structure resolution has become higher, which also puts forward new requirements to the FOH array.

To satisfy these requirements, many new techniques in the FOH field have been proposed and researched in detail. First, large-scale FOH arrays have been investigated to improve the detection performance of underwater acoustic signals. Second, considering that very-low-frequency noise (<100 Hz) is the main noise source of underwater targets, the very-low-frequency detection is rather important for the military application of FOH. Third, fiber-optic vector hydrophone (FOVH) has also been widely researched because it can provide more complete information than the scalar one. Fourth, the towed linear array has drawn much attention due to its small diameter and flexibility to size-limited platforms. Finally, the FOH application is also moving towards the deep sea and long-haul transmission, so the pressure resistant performance and the fiber nonlinearity which were neglected before have become significant. In this paper, we review the recent progress in FOH from the aforementioned five aspects.

## 2. Large-scale FOH array

For the traditional acoustic pressure FOH, it can be treated as scalar FOH without directivity, and the target direction is obtained by the beam-forming of the FOH array. The beamwidth as well as the direction precision depends on the array scale, so the large-scale array is used to improve the direction precision of the underwater target. Moreover, the large-scale array can improve the spatial signal-to-noise gain, which leads to an increase in the detection range. Therefore, expanding the array scale is significant for the performance improvement of the FOH array. There are many methods to expand the array scale such as space division multiplexing (SDM), wavelength division multiplexing (WDM), and time division multiplexing (TDM). To be noticed, compared with the large-scale optical communication system, the scale of the FOH array is usually smaller because FOH uses not digital signals but analog ones. On this condition, the array loss must be paid more attention. That is to say, with an increase in the array scale, the array will suffer larger loss resulting from more optical components. Therefore, it is a key technique to improve the overall performance of the FOH array by enlarging the array scale.

Fig. 1 Fiber-optic hydrophone array in USS Virginia [7].

Since more than twenty years ago, many organizations in the world have demonstrated various large-scale FOH arrays [53–66]. As the organization that invents the first FOH, United States Naval Research Laboratory (NRL) has achieved great success in the application of the FOH array. In 1990, NRL conducted its first deployment of a 48-channel all optical towed array [67]. NRL completed a few FOH array trials from 1990s to 2000s. In 2003, the first lightweight wide aperture array (LWWAA) consisting of 2 700 sensors went into service with the launch of USS Virginia, as shown in Fig. 1 [7, 68], which was a milestone in the development history of FOH. On the other hand, the large-scale FOH array gains much interest in the civilian field such as oil and gas exploration. In 2010, the Optoplan deployed a fiber ocean bottom seismic cable (OBC) system for the permanent reservoir monitoring at the Ekofisk filed in the North Sea, which consisted of 16 000 sensors in the wet end, as shown in Fig. 2. This project is the largest fiber optic sensor network in the world to the best of our knowledge [69]. In 2013, a distributed amplified hybrid dense wavelength division multiplexing (DWDM) and TDM array architecture for the large-scale interferometric fiber-optic sensor array system was demonstrated, as shown in Fig. 3, which showed the potential for multiplexing and interrogating up to 4 096 sensors using a single fiber pair [63]. The array scale can be further enlarged by increasing the number of channels. In recent years, China has also developed the large-scale FOH array for scientific research and an FOH array with 1 024 sensors has been reported [66].

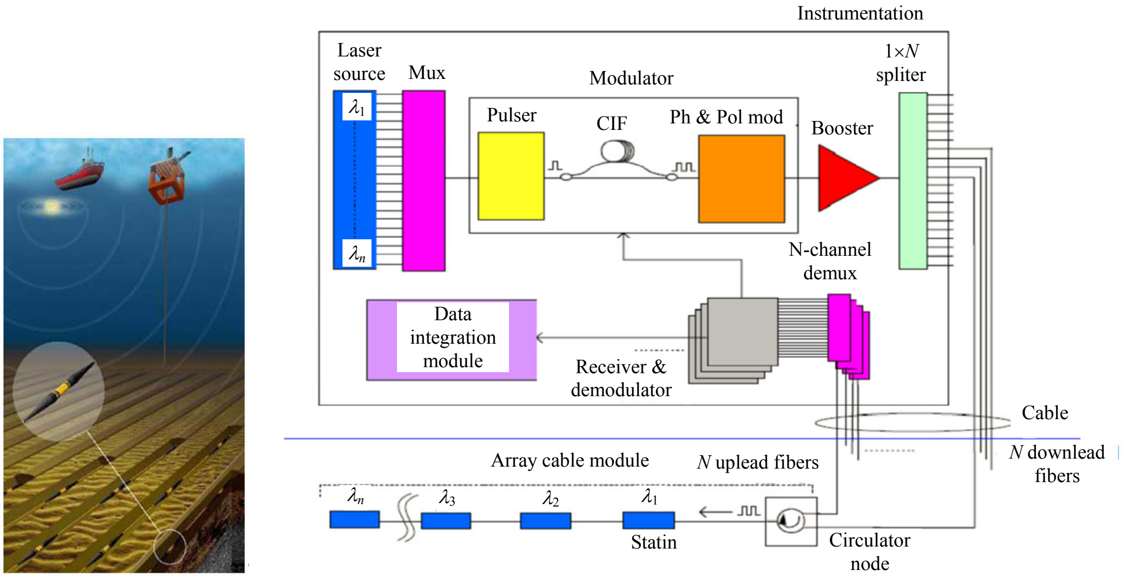

Fig. 2 Structure of the Optoplan array.

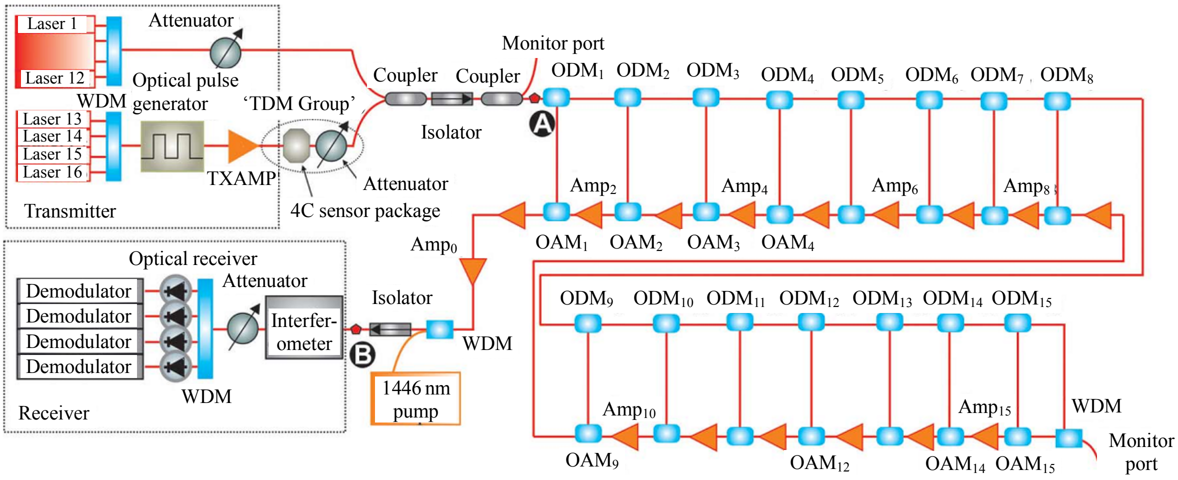

Fig. 3 Array architecture in [63].

## 3. Very-low-frequency detection of FOH

As mentioned above, the very-low-frequency noise (<100 Hz) accounts for the main part of underwater target noise. Compared with higher frequency, it is difficult to reduce the very-low-frequency characteristic signals of underwater targets. So the very-low-frequency noise is used to detect underwater targets. Also, the spatial and time coherence is strong for the very-low-frequency signals, leading to a high gain when a mass of sensors are used for long-time accumulation. It has also to be noticed that the very-low-frequency acoustic signals can propagate farther because of lower transmission loss. Therefore, it is promising to develop very-low-frequency FOH to realize the detection of underwater targets.

Due to the striking military background, the reports on the very-low-frequency detection are not sufficient. A relevant but not recent report was given by an Australian group that their fiber laser hydrophone possessed a flat acoustic responsivity of 110 dB re Hz/Pa from 40 Hz to 1 kHz, while a decrease was observed at the band lower than 40 Hz [70]. NRL demonstrated that the practical acoustic responsivity of their distributed feedback fiber laser (DFB FL) based scalar FOH was 107 dB re Hz/Pa over the bandwidth from 100 Hz to 5 kHz, which agreed well with the theoretically predicted value. However, as for the very-low-frequency band, they only provided the theoretical prediction between 30 Hz and 100 Hz due to the limitations of the underwater acoustic projector [71]. Recently, researchers in Russia have reported a hydrophone used in their towed array, but the acoustic pressure responsivity is not a flat pattern from 20 Hz to 495 Hz [72]. In contrast, a report from China has shown that the acoustic sensitivity is about 115 dB re Hz/Pa between 10 Hz and 10 kHz for their DFB FL-style FOH, which has improved the very-low-frequency detection ability compared with other designs [73]. The researchers from National University of Defense Technology (NUDT) have also investigated very-low-frequency interferometric FOH with a sensitivity of –116 dB re rad/μPa between 10 Hz and 2 kHz, phase noise of –102 dB re rad/$\text{Hz}^{1/2}$ @100 Hz, and equivalent noise pressure of 14 dB @100 Hz re μPa/$\text{Hz}^{1/2}$, as shown in Figs. 4–6. This equivalent noise pressure is far below the ocean ambient noise, making the very-low-frequency FOH a good choice for remote detection of underwater targets.

Fig. 4 Very-low-frequency interferometric FOH sensor head.

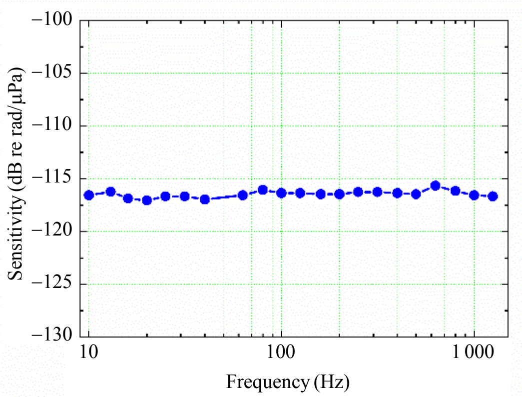

Fig. 5 Sensitivity of the very-low-frequency FOH.

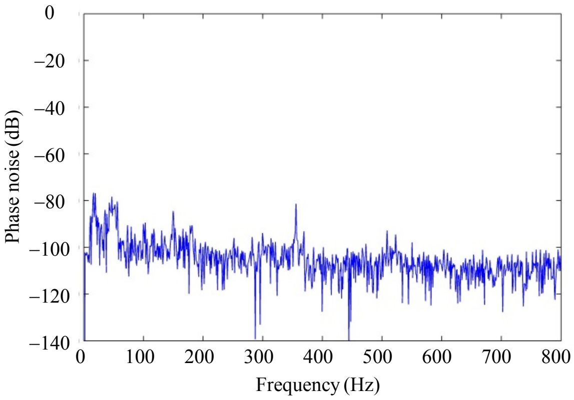

Fig. 6 Phase noise of the very-low-frequency FOH.

## 4. Fiber-optic vector hydrophone (FOVH)

Compared with the traditional scalar FOH, FOVH is generally composed of acoustic pressure hydrophone as well as three orthogonally mounted fiber accelerometers, which can obtain more complete acoustic information. For the FOVH, the cardioid directivity can be achieved with the linear combination of acoustic pressure and vibration velocity, and a spatial gain of 4.8 dB–6 dB is obtained accordingly. As a result, through only one point detection, the isotropic noise is suppressed and the port and starboard ambiguity is removed, which finally increases the detection range. Moreover, the directivity of the FOVH has no relation with the frequency, and the size of the FOVH array is smaller than that of the FOH array for the same technique specifications. Based on the above advantages, FOVH plays a key role in many military applications, especially in subsurface buoy and size-limited platforms.

The desired accelerometer that can be used in FOVH was firstly reported in the 1980’s [74] and has experienced fast development in the past four decades [75–81]. On one hand, in terms of the structure, the general optical fiber accelerometer is a simple spring-mass system operating below the structural resonant frequency, but the concrete form is diverse. The compliant cylinder design appeared firstly [75] and has reached a mature level to date, which is generally adopted by researchers in Europe and Asia [80–87]. Most recently, a geophone for seismic monitoring, which consists of three orthogonal accelerometers based on the Michelson interferometers wounded on the compliant cylinders, has been reported during the years from 2017 to 2020, which possesses an operation bandwidth of 2 Hz to 150 Hz, an acceleration responsivity of above 50 dB re rad/g, and a transverse suppression ratio of 30 dB [87]. The researchers from NUDT have investigated a FOVH with an acceleration sensitivity of 49 dB re rad/g, sensitivity fluctuation of <±0.7 dB, and an orthogonal crosstalk of <–52.9 dB, as shown in Figs. 7–9, and the developed FOVH has a 66 MPa pressure resistant performance, which can be used in the 6 000 m deep sea. At the same time, in order to further explore the possibility for military applications, the institutes in US and Australia, represented by NRL, have turned their attention to the architecture based on a spring disk or beam since the beginning of 2000’s, which possesses a more miniaturized, compact, and lightweight structure [88–90]. Relevant researches can only be traced back to the report in 2009, where a DFB FL is bonded to the surface of a flexural bend beam so that the operating wavelength can be modulated with the strain-induced flexion of the beam, achieving an acceleration responsivity of 142 dB re Hz/m·s$^{-2}$ from 10 Hz to 1.5 kHz, and a transverse suppression ratio exceeding 20 dB [89].

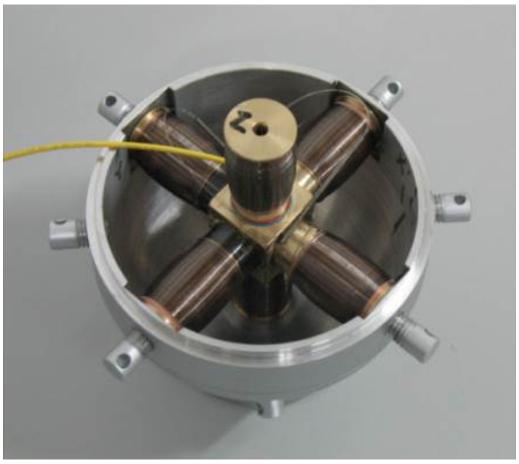

Fig. 7 Structure of FOVH.

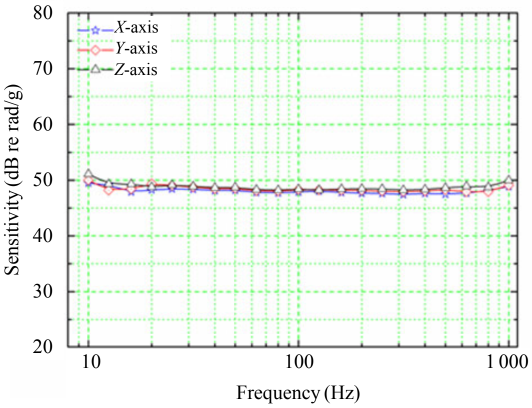

Fig. 8 Acceleration sensitivity of FOVH.

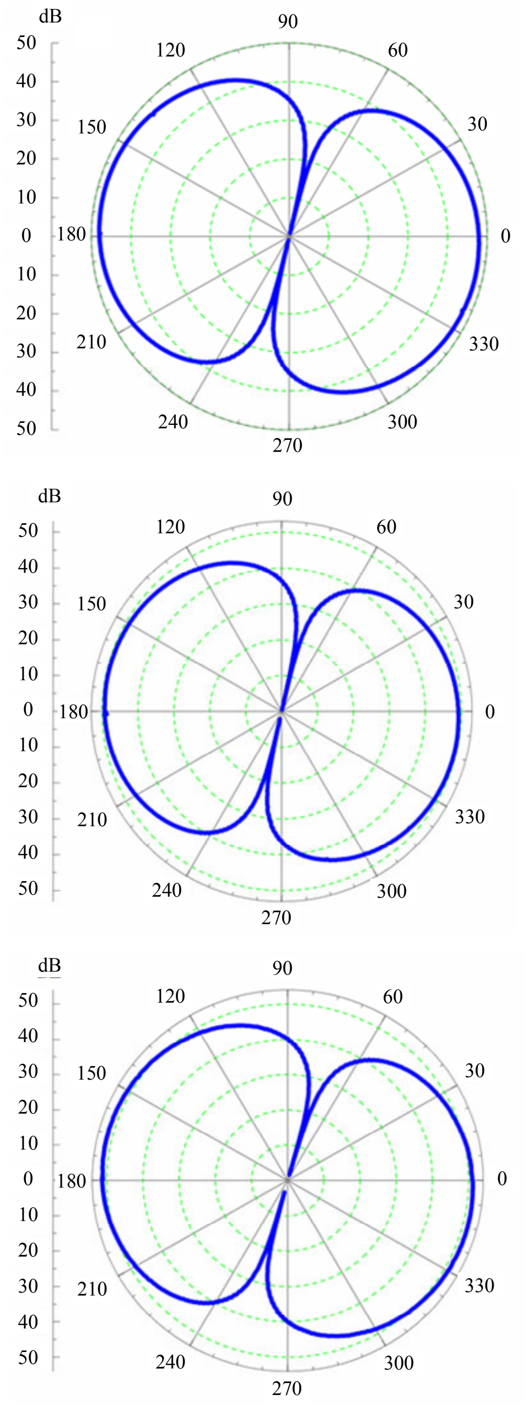

Fig. 9 Three-axis directivity of FOVH at the frequency of 160 Hz.

On the other hand, as for the sensing mechanism of the optical fiber accelerometer, the earliest and maturest scheme is based on the optical fiber interferometer, which is called the interferometric accelerometer [77, 80, 81, 85–87]. Nevertheless, the emphases have been put on the sensing schemes based on the fiber Bragg grating (FBG) or the DFB FL by European [82–84] and USA researchers since middle 2000's, and the major concern is still the miniaturization of the design. Representatively, in terms of the FOVH, NRL has devoted most of the resources to the researches on the DFB FL-style one in the past 15 years, owing mainly to its striking advantages such as the small size and low noise [83]. The excellent achievement has also been reported in [79]. It should be pointed out that the DFB FL-style FOVH requires a fundamentally well-performed DFB FL with the intrinsic phase and intensity noise as low as possible. As a result, the researchers in NRL have never ceased exploiting the optimum performance of the DFB FL and have proposed complete theory in the recent report [91], which has marked the maturity of the DFB FL used for FOVH. In China, most recently, the typical FBG-type accelerometer has been reported to possess a flat acceleration sensitivity of 42 dB over the bandwidth from 20 Hz to 200 Hz [92], while the reported DFB FL-type one has the properties of a flat acceleration sensitivity of 33 dB re pm/g over the bandwidth from 5 Hz to 300 Hz [93].

Besides the accelerometer-type FOVH, NRL has also reported a velocity-style vector sensor on basis of a DFB FL bonded on a planar cantilever, which has pioneered in detecting the underwater acoustic particle velocity [94–96]. The ingenious design makes the sensor respond to the acoustic field with frequency independence and maintains the sensitivity over the operating bandwidth, overcoming the disadvantage of the accelerometer-type FOVH that the acoustic sensitivity diminishes with the decreasing frequency.

## 5. Towed linear array of FOH

Towed linear array is another typical application of the FOH and it is also suitable for the size-limited platforms. The main problem for towed linear array is the flow noise, which is difficult to remove. After many years of development, it is ensured that the flow noise remains almost the same level as the diameter of towed linear array decreases, leading to the improvement of general performance.

The FOH was originally demonstrated by NRL to serve as the element of the towed linear array in 1970’s, and the mature sign of the technology is the launch of the USS Virginia in 2003 which is equipped with a thinline towed array named as TB-33 [97]. Considering the suppression of the intrinsic noise and the prospective application on the mini underwater vehicles like the unmanned underwater vehicle (UUV), the development of the towed linear array has one trend towards designing a thinner towed cable. A report showed that an Australian-designed array had a practical diameter of only 25 mm, which reached the advanced level at that time [98]. The reports from other countries have appeared successively in recent years. It was reported by an Indian group that their demonstration possesses an outer diameter of 32 mm [99]. The researchers from Russia reported an interferometric towed linear array with an outer diameter of 20 mm, which is a real challenge for the interferometric scheme [72]. Almost simultaneously, Chinese researchers reported a sea trial using a 16-element DFB-FL based towed linear array with a diameter of only 12 mm, and the towed noise of the array was 69 dB re mPa/Hz$^{1/2}$ @1 kHz [100]. The researchers from NUDT carried out a lake trial with the 32-element FOH towed linear array and obtained a towed noise of 75 dB re μPa/Hz$^{1/2}$ @100 Hz at the speed of 6 knots, as shown in Figs. 10 and 11. Furthermore, they proposed a dynamic depth estimation method using the towed linear array [101].

Fig. 10 FOH towed array.

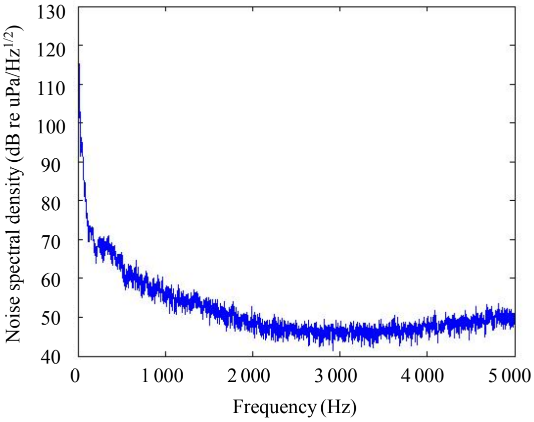

Fig. 11 Noise spectrum of towed array.

Another research focus lies in monitoring the gesture of the towed linear array. Recently, many researchers have put forward various methods to estimate the shape of the towed linear array and provided guidelines for the practical applications of the towed linear array [102–104].

## 6. Deep-sea and long-haul transmission

Owing to the advantage of detecting acoustic targets through deep-sea reliable acoustic path, the researches of the FOH move towards deep-sea application. The FOH and FOVH designed by NUDT have passed 66 MPa pressure resistant test, which have the potential for being used in the sea as deep as 6000 m. At the same time, with the developments of erbium-doped fiber amplifier (EDFA) and fiber Raman amplifier (FRA), the FOH system develops towards the direction of long-haul fiber transmission [52, 105–109]. There are two types of systems to realize long-haul fiber transmission, i.e., the repeater one and the repeaterless one. For the former, the transmission distance can reach almost 1 000 km, while it can reach 120 km for the latter. To be noticed, the above distance is generally shorter than that of the long-haul fiber communication system, because the digital signals are used in fiber communication while the analog signals are used in fiber sensing. For the repeater system, the aforementioned Optoplan OBC system reached a 200 km transmission distance [69]. An FOH system with transmission distance as long as 500 km was also reported [60]. In China, researchers from NUDT have developed an FOH array with the fiber transmission distance as long as 400 km using the cascaded-amplifier technique, as shown in Fig. 12, and the phase noise is about –90 dB re rad/Hz$^{1/2}$@1 kHz after the long-haul transmission [110]. On the other hand, for the repeaterless system, with the longer transmission distance, various nonlinear effects become dominant, which leads to large power depletion and serious phase noise. As a result, the performance of the FOH array is degraded seriously [111].

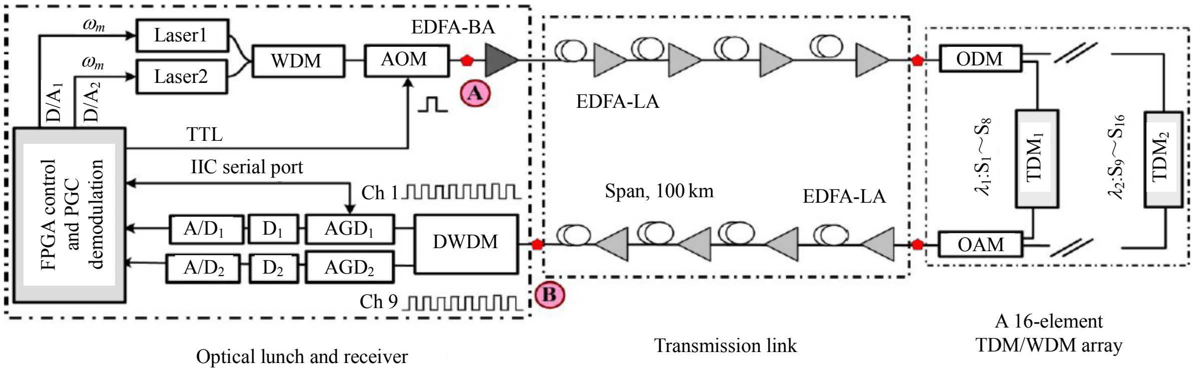

Fig. 12 400 km FOH system configuration in [110].

The maximum input power for fiber transmission is primarily limited by a nonlinear effect named as stimulated Brillouin scatting (SBS), which has the lowest threshold in the long fiber [112]. So the suppression of SBS in the long-haul FOH array is necessary. Many researchers studied the SBS suppression problem in various optical systems [113–119]. In the interferometric FOH system, the phase modulation method shows a great potential in SBS suppression for its convenience and high efficiency [120]. The effect of phase modulation on phase noise was studied in the interferometric fiber sensing systems, and the excess phase noise induced by phase modulation was observed in the experiment, which set a limit to the application of phase modulation [117]. A novel optical modulation method was proposed to suppress the phase modulation induced excess phase noise. However, theoretical analysis has not been derived to explain the excess phase noise in [117]. A detailed analysis was derived about the excess phase noise in the interferometric fiber sensing system, and a matching condition was proposed to suppress the excess phase noise [121], as shown in Figs. 13 and 14. As a result, SBS can be completely suppressed in the long-haul FOH system by increasing the number of the modulation sidebands.

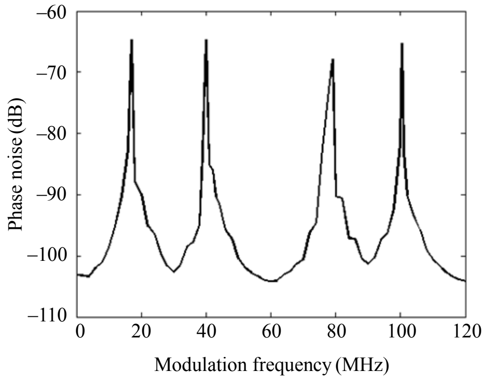

Fig. 13 Phase noise versus phase modulation frequency in [121].

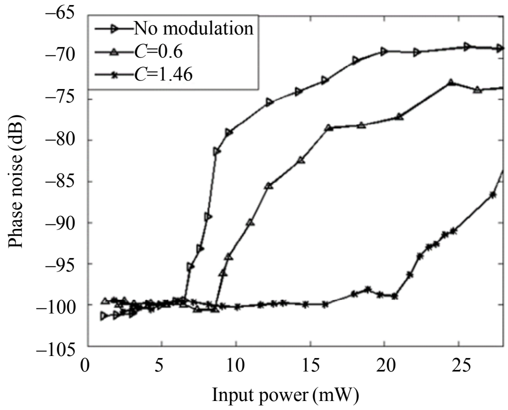

Fig. 14 Phase noise versus input power with different modulation indexes in [121].

Once the SBS is effectively suppressed, another nonlinear effect named as modulation instability (MI) becomes dominant especially in the TDM system where optical pulses are used. The occurrence of MI generates symmetric sidebands by amplifying the amplified spontaneous emission (ASE) noise, which leads to serious phase noise [122]. Optical narrowband filtering is a direct solution to suppress MI, which is achieved by decreasing the ASE noise that seeds MI [123]. Orthogonal polarization pulses can increase MI threshold by 3 dB [124]. A method called time and frequency pump-probe multiplexing can increase MI threshold by $N$ times ($N$ is the number of spectral components), but the experimental setup is very complicated [125]. Spontaneous MI as well as the phase noise was suppressed with coherent seeds in the interferometric fiber sensing systems [126], as shown in Fig. 15, and the results showed that the average phase noise can be as low as about –90 dB re rad/Hz$^{1/2}$ @1 kHz when the input power is 800 mW, as shown in Fig. 16.

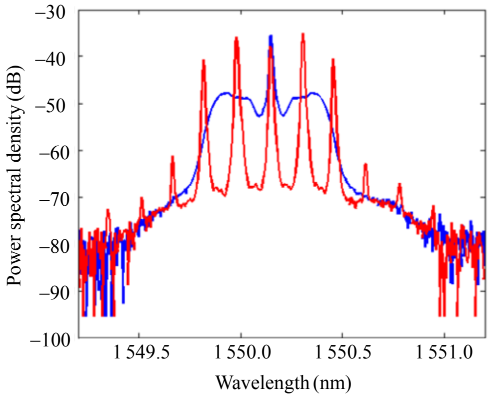

Fig. 15 Output spectra with an input power of 400 mW (blue: without seed; red: with seed).

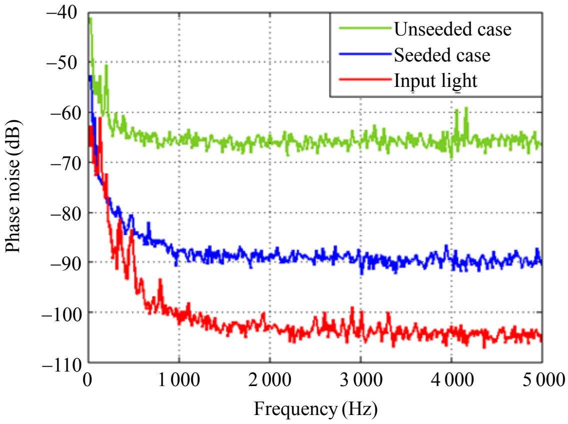

Fig. 16 Output phase noise without and with seed and the phase noise of the input light ($P$=800 mW).

## 7. Conclusions

In summary, to make the research progress of FOH clear, five aspects are reviewed in detail, including large-scale FOH array, very-low-frequency detection, fiber-optic vector hydrophone (FOVH), towed linear array, and deep-sea and long-haul transmission. The mentioned techniques will be very helpful for the research and practical applications in the FOH field. Furthermore, a great deal of advanced technologies based on new materials, new mechanisms, and new structures are expected to be used in the FOH to improve its characteristics and enlarge its applications in the near future.

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## References

[1] J. A. Bucaro, H. D. Dardy, and E. F. Carome, “Optical fiber acoustic sensor,” *Applied Optics*, 1977, 16(7): 1761–1762.

[2] C. K. Kirdendall and A. Dandridge, “Overview of high performance fibre-optic sensing,” *Journal of Physics D: Applied Physics*, 2004, 37(18): 197–216.

[3] A. D. Kersey and A. Dandridge, “Multiplexed Mach-Zehnder ladder array with ten sensor elements,” *Electronics Letters*, 1989, 25(19): 1298–1299.

[4] A. Dandridge and G. B. Cogdell, “Fiber optic sensors for navy applications,” *IEEE LCS*, 1991, 2(1): 81–89.

[5] A. R. Davis, C. K. Kirdendall, A. Dandridge, and A. D. Kersey, “64-channel all-optical deployable array,” in *Proceedings of 12th International*

*Conference on Optical Fiber Sensors*, Williamsburg, United State, 1997, DOI: doi.org/10.1364/OFS.1997.OFA6.

[6] G. A. Cranch, C. K. Kirdendall, K. Daley, S. Motley, A. Bautista, J. Salzano, *et al.*, "Large-scale remotely pumped and interrogated fiber-optic interferometric sensor array," *IEEE Photonics Technology Letters*, 2003, 15(11): 1579–1581.

[7] A. Dandridge, A. B. Tevten, and C. K. Kirdendall, "Development of the fiber optic wide aperture array: from initial development to production," *NRL Review*, 2004: 177–179.

[8] J. H. Cole, C. Kirkendall, A. Dandridge, G. Cogdell, and T. G. Giallorenzi, "Twenty-five years of interferometeric fiber optic acoustic sensors at the Naval Research Laboratory," *Journal of the Washington Academy of Sciences*, 2004, 90(3): 40–57.

[9] G. A. Cranch, R. Crickmre, C. K. Kirkendall, A. Bautista, K. Daley, S. Motley, *et al.*, "Acoustic performance of a large-aperture, seabed, fiber-optic hydrophone array," *The Journal of the Acoustical Society of America*, 2004, 115(6): 2848–2858.

[10] G. A. Cranch, G. M. H. Flockhart, and C. K. Kirdendall, "Efficient fiber Bragg grating and fiber Fabry-Perot sensor multiplexing scheme using a broadband pulsed mode-locked laser," *Journal of Lightwave Technology*, 2005, 23(11): 3798–3807.

[11] K. Clay, H. C. James, and B. T. Alan, "Progress in fiber optic acoustic and seismic sensing," in *Proceedings of International Conference on Optical Fibre Sensors*, Mexico, 2006, pp. THB1.

[12] C. K. Kirdendall, T. Barock, and A. Tevten, "Fiber optic towed arrays," *NRL Review*, 2007: 121–123.

[13] C. K. Kirdendall, R. Bartolo, and J. Salzano, "Distributed fiber optic sensing for homeland security," *NRL Review*, 2007: 195–196.

[14] C. W. Hodgson, M. J. Digonnet, and H. J. Shaw, "Large-scale interferometric fiber sensor arrays with multiple optical amplifiers," *Optics Letters*, 1997, 22(21): 1651–1653.（two???）

[15] C. W. Hodgson, J. L. Wagener, and M. J. F. Digonnet, "Optimization of large-scale fiber sensor arrays incorporating multiple optical amplifiers-Part I: signal-to-noise ratio," *Journal of Lightwave Technology*, 1998, 16(2): 218–223.

[16] C. W. Hodgson, J. L. Wagener, and M. J. F. Digonnet, "Optimization of large-scale fiber sensor array incorporating multiple optical amplifiers-Part2: pump power," *Journal of Lightwave Technology*, 1998, 16(2): 224–231.

[17] M. J. F. Digonnet, B. J. Vakoc, C. W. Hodgson, and G. S. Kino, "Acoustic fiber sensor arrays," in *Proceeding of Second European Workshop on Optical Fibre Sensors*, Santander, Spain, 2004, pp. 39–50.

[18] B. J. Vakoc, M. J. F. Diagonnet, and G. S. Kino, "Demonstration of a 16-sensor time-division-multiplexed sagnac-interferometer- based acoustic sensor array with an amplified telemetry and a polarization-based biasing scheme," in *Proceedings of 15th Optical Fiber Sensors Conference Technical Digest*, Portland, USA, 2002.

[19] P. J. Nash, "Review of interferometric optical fibre hydrophone technology," *Processing of Radar, Sonar and Navigation*, 1996, 143(3): 204–209.

[20] P. J. Nash, G. A. Granch, L. K. Cheng, D. Bruijn, and I. Crowe, "32 element TDM optical hydrophone array," in *Proceedings of European Workshop on Optical Fibre Sensors*, Peebles, United Kingdom, 1998, pp. 238–242.

[21] D. J. Hill, P. J. Nash, S. D. Hawker, and I. Bennion, "Progress toward an ultrathin optical hydrophone array," in *Proceedings of European Workshop on Optical Fibre Sensors*, Peebles, United Kingdom, 1998, pp. 301–304.

[22] P. J. Nash, G. A. Cranch, and D. J. Hill, "Large scale multiplexed fiber optic arrays for geophysical applications," in *Industrial Sensing Systems*, United States, 2000, pp. 55–65.

[23] G. A. Cranch and P. J. Nash, "Large-scale multiplexing of interferometric fiber-optic sensors using TDM and DWDM," *Journal of Lightwave Technology*, 2001, 19(5): 687–699.

[24] P. J. Nash, J. Latchem, G. A. Cranch, S. Motley, A. Bautista, C. K. Kirkendall, *et al.*, "Design, development and construction of fibre-optic bottom mounted array," in *Proceedings of 15th Optical Fiber Sensors Conference Technical Digest (OFS)*, Portland, USA, 2002, pp. 333–336.

[25] G. A. Cranch, P. J. Nash, and C. K. Kirkendall, "Large-scale remotely interrogated arrays of fiber-optic interferometric sensors for underwater acoustic applications," *IEEE Sensors Journal*, 2003, 3(1): 19–30.

[26] D. J. Hill, "The evolution and exploitation of the fibre-optic hydrophone," in *Proceedings of Third European Workshop on Optical Fibre Sensors*, Napoli, Italy, 2007, pp. 661907-1–661907-4.

[27] H. Nakstad and J. T. Kringlebotn, "Realisation of a full-scale fibre optic ocean bottom seismic system," in *Proceedings of 19th International Conference on Optical Fibre Sensors*, Australia, 2008, pp. 700436-1–700436-4.

[28] O. H. Waagaard, E. Rønnekleiv, S. Forbord, and D. Thingbo, "Reduction of crosstalk in inline sensor arrays using inverse scattering," in *Proceedings of 19th International Conference on Optical Fibre Sensors*, Australia, 2008, pp. 70044Z-1–70044Z-4.

[29] O. H. Waagaard, E. Rønnekleiv, S. Forbord, and D. Thingbo, "Suppression of cable induced noise in an interferometric sensor system," in *Proceedings of 20th International Conference on Optical Fibre Sensors*, United Kingdom, 2009, pp. 75034Q-1–

75034Q-4.

[30] E. Rønnekleiv, O. H. Waagaard, D. Thingbo, and S. Forbord, "Suppression of Rayleigh scattering noise in a TDM multiplexed interferometric sensor system," in *Proceedings of Optical Fiber Communication Conference/National Fiber Optic Engineers Conference*, San Diego, USA, 2008, pp. OMT4.

[31] Y. Hu, Z. Hu, H. Luo, L. Ma, S. Xiong, Y. Liao, *et al.*, "Recent progress toward fiber optic hydrophone research, application and commercialization in China," in *Proceedings of OFS2012 22nd International Conference on Optical Fiber Sensors*, China, 2012, pp. 84210Q.

[32] Y. Hu, "All polarization-holding fiber polarizer," Ph.D. dissertation, Tsinghua University, China, 1999.

[33] M. Zhou, Y. Hu, S. Xiong, Y. Liu, M. Ni, and X. Zhang, "All polarization maintaining fiber hydrophone array," *Chinese Journal of Lasers*, 2002, 29(5): 415–417.

[34] M. Ni, S. Xiong, Z. Meng, and R. Zhang, "Realization of digital demodulation of the phase generated-carrier technique in fiber optic hydrophone system," *Applied Acoustics*, 2004, 23(6): 5–11.

[35] Z. Wang, Y. Hu, Z. Meng, H. Luo, and M. Ni, "Novel mechanical antialiasing fiber-optic hydrophone with a fourth-order acoustic low-pass filter," *Optics Letters*, 2008, 33(11): 1267–1269.

[36] Y. Hu, Z. Meng, S. Xiong, Y. Liu, and X. Zhang, "Development of interferometric all polarization maintaining fiber hydrophone array," *Acta Acustica*, 2003, 28(2): 155–158.

[37] M. Ni, H. Yang, S. Xiong, and Y. Hu, "Investigation of polarization-induced fading in fiber optic interferometers with polarizer-based polarization diversity receivers," *Applied Optics*, 2006, 45(11): 2387–2390.

[38] M. Ni, Y. Hu, Z. Meng, and R. Zhang, "Study on fiber optic hydrophone unit," *Applied Acoustics*, 2003, 22(2): 1–7.

[39] Z. Meng, Y. Hu, M. Ni, S. Xiong, R. Zhang, X. Li, *et al.*, "Development of a 32-element fibre optic hydrophone system," in *Proceedings of Fiber Optic Sensor Technology and Applications III*, Beilingham, USA, 2004, pp. 114–116.

[40] S. Xiong, "Research on the fiber optic vector hydrophone," Ph.D. dissertation, National University of Defense Technology, China, 2003.

[41] S. Xiong, H. Luo, Y. Hu, and Z. Meng, "Research on interferometric polarization maintaining fiber optic micro-vibration vector sensor," *Chinese Journal of Lasers*, 2004, 31(7): 843–847.

[42] H. Zhang, M. Zhang, L. Wang, Y. Liao, and D. N. Wang, "Output noise analysis of optical fiber interferometric sensors using a 3×3 coupler," *Measurement Science and Technology*, 2011, 22(12): 125203–125211.

[43] H. Zhang, M. Zhang, L. Wang, Y. Liao, D. N. Wang, and Y. Zhu, "An improved PGC demodulation method to suppress the impact of laser intensity modulation," in *Proceedings of 2011 International Conference on Optical Instruments and Technology: Optical Sensors and Applications*, China, 2011, pp. 81990Q.

[44] C. Tian, L. Wang, M. Zhang, H. Zhang, X. Chu, S. Lai, *et al.*, "Performance improvement of PGC method by using lookup table for optical seismometer," in *Proceedings of 20th International Conference on Optical Fibre Sensors*, United Kingdom, 2009, pp. 750348.

[45] W. Rao, "Study on key techniques of fiber optic vector hydrophone towed array for high resolution seafloor strata detection," Ph.D. dissertation, National University of Defense Technology, China, 2012.

[46] H. Luo, S. Xiong, Y. Hu, Z. Meng, and M. Ni, "Research on all polarization-maintaining fiber optic accelerometer," in *Proceedings of Fiber Optic Sensor Technology and Applications IV*, United States, 2005, pp. 60040R1-7.

[47] J. Wang, H. Luo, Z. Meng, and Y. Hu, "Experimental research of an all-polarization-maintaining optical fiber vector hydrophone," *Journal of Lightwave Technology*, 2012, 30(8): 1178–1184.

[48] Y. Wu, "Study on key techniques of fiber optic vector hydrophone for towed line array applications," Ph.D. dissertation, National University of Defense technology, China, 2011.

[49] S. Niu, Y. Hu, Z. Hu, and H. Luo, "Fiber Fabry-Pérot hydrophone based on push-pull structure and differential detection," *IEEE Photonics Technology Letters*, 2011, 23(20): 1499–1501.

[50] L. Ma, Y. Hu, H. Luo, and Z. Hu, "DFB fiber laser hydrophone with flat frequency response and enhanced acoustic pressure sensitivity," *IEEE Photonics Technology Letters*, 2009, 21(17): 1280–1282.

[51] W. Chen, "Influences and suppression techniques of nonlinear effects on long-haul interferometric fiber sensing systems," Ph.D. dissertation, National University of Defense Technology, China, 2013.

[52] C. Cao, "Study on key techniques of high performance fiber-optics hydrophone array based on ultra-remotely optical transmission and cascaded amplifiers," Ph.D. dissertation, National University of Defense Technology, China, 2013.

[53] G. A. Cranch and P. J. Nash, "High multiplexing gain using TDM and WDM in interferometric sensor arrays," in *Proceedings of Fiber Optic Sensor Technology and Applications*, United States, 1999.

[54] C. W. Hodgson and B. J. Vakoc, "Large scale

WDM/TDM sensor array employing erbium-doped fiber amplifiers," United States, U.S. Patent 6,282,334, August 28, 2001.

[55] P. J. Nash, J. Latchem, G. A. Cranch, S. Motley, A. Bautista, C. K. Kirkendall, *et al.*, "Design, development and construction of fibre-optic bottom mounted array," in *Proceedings of 15th Optical Fiber Sensors Conference Technical Digest (OFS)*, Portland, USA, 2002, pp. 333–336.

[56] O. Farsund, C. Erbeia, C. Lachaize, A. Hordvik, K. Nakken, A. Berg, *et al.*, "Design and field test of a 32-element fiber optic hydrophone system," in *Proceedings of 2002 15th Optical Fiber Sensors Conference Technical Digest*, Portland, USA, 2002.

[57] Y. Shindo, T. Yoshikawa, and H. Mikada, "A large scale seismic sensing array on the seafloor with fiber optic accelerometers," in *Proceedings of Sensors, IEEE*, Orlando, USA, 2002.

[58] G. A. Cranch, C. K. Kirkendall, K. Daley, S. Motley, A. Bautista, J. Salzano, *et al.*, "Large-scale remotely pumped and interrogated fiber-optic interferometric sensor array," *IEEE Photonics Technology Letters*, 2003, 15(11): 1579–1581.

[59] D. Hill and P. Nash, "Fibre-optic hydrophone array for acoustic surveillance in the littoral," in *Proceedings of Photonics for Port and Harbor Security*, United States, 2005.

[60] E. Austin, Q. Zhang, S. Alam, M. Zervas, R. Slavik, P. Petropoulos, *et al.*, "500km remote interrogation of optical sensor arrays," in *Proceedings of 21st International Conference on Optical Fibre Sensors (OFS21)*, Canada, 2011.

[61] O. C. Akkaya, M. J. F. Digonnet, G. S. Kino, and O. Solgaard, "Time-division-multiplexed interferometric sensor arrays," *Journal of Lightwave Technology*, 2013, 31(16): 2701–2708.

[62] Y. Liao, E. Austin, P. J. Nash, S. A. Kingsley, and D. J. Richardson, "High performance architecture design for large scale fibre-optic sensor arrays using distributed EDFAs and hybrid TDM/DWDM," *Measurement Science and Technology*, 2013, 24(9): 094024.

[63] Y. Liao, E. Austin, P. J. Nash, S. A. Kingsley, and D. J. Richardson, "Highly scaled amplified hybrid TDM/DWDM array architecture for interferometric fiber-optic sensor systems," *Journal of Lightwave Technology*, 2013, 31(6): 882–888.

[64] V. S. Lavrov, M. Y. Plotnikov, S. M. Aksarin, M. E. Efimov, V. A. Shulepov, A. V. Kulikov, *et al.*, "Experimental investigation of the thin fiber-optic hydrophone array based on fiber Bragg gratings," *Optical Fiber Technology*, 2017, 34(3): 47–51.

[65] P. J. Nash and G. A. Cranch, "Multi-channel optical hydrophone array with time and wavelength division multiplexing," in *Proceedings of 13th International Conference on Optical Fiber Sensors*, Kyongju, Republic of Korea, 1999, pp. 374613

[66] X. Hao, H. Zhang, C. Wei, C. Wang, and H. Zhang, "Sea trial for fiber-optic hydrophone array used in marine geophysical exploration," *Journal of Tropical Oceanography*, 2018, 37(3): 93–98 (in Chinese).

[67] A. Dandridge, A. M. Yurek, and A. B. Tveten, "All optical towed array (AOTA) tow test results," in *AFCEA'90*, McLean, USA, 1990.

[68] A. Dandridge, "Fiber optic interferometric sensors at sea," *Optics and Photonics News*, 2019, 30(6): 34–41.

[69] M. Eriksrud, "Seabed permanent reservoir monitoring (PRM)-A valid 4D seismic technology for fields in the North Sea," *First break*, 2014, 32(5): 67–73.

[70] S. Goodman, S. Foster, J. V. Velzen, and H. Mendis, "Field demonstration of a DFB fibre laser hydrophone seabed array in Jervis Bay, Australia," in *Proceedings of 20th International Conference on Optical Fibre Sensors*, United Kingdom, 2009, pp. 75034L.

[71] S. Foster, A. Tikhomirov, and V. J. Van, "Towards a high performance fiber laser hydrophone," *Journal of Lightwave Technology*, 2011, 29(9): 1335–1342.

[72] M. Y. Plotnikov, V. S. Lavrov, P. Y. Dmitraschenko, A. V. Kulikov, and I. K. Meshkovsky, "Thin cable fiber-optic hydrophone array for passive acoustic surveillance applications," *IEEE Sensors Journal*, 2019, 19(9): 3376–3382.

[73] M. Li, Z. Sun, X. Zhang, S. Li, Z. Song, M. Wang, *et al.*, "Development of high sensitivity eight-element multiplexed fiber laser acoustic pressure hydrophone array and interrogation system," *Photonic Sensors*, 2017, 7(3): 253–260.

[74] A. B. Tveten, A. D. Dandridge, C. M. Davis, and T. G. Giallorenzi, "Fibre optic accelerometer," *Electronics Letters*, 1980, 16(22): 854–856.

[75] A. D. Kersey, D. A. Jackson, and M. Corke, "High-sensitivity fibre-optic accelerometer," *Electronics Letters*, 1982, 18(13): 559–561.

[76] R. D. Pechstedt and D. A. Jackson, "Performance analysis of a fiber optic accelerometer based on a compliant cylinder design," *Review of Scientific Instruments*, 1995, 66(1): 207–214.

[77] G. A. Cranch and P. J. Nash, "High-responsivity fiber-optic flexural disk accelerometers," *Journal of Lightwave Technology*, 2000, 18(9): 1233–1243.

[78] G. H. Ames and J. M. Maguire, "Erbium fiber laser accelerometer," *IEEE Sensors Journal*, 2007, 7(4): 557–561.

[79] P. Jackson, S. Foster, and S. Goodman, "A fibre laser acoustic vector sensor," in *Proceedings of 20th International Conference on Optical Fibre Sensors*, Edinburgh, UK, 2009, pp. 750329.

[80] J. Wang, H. Luo, Z. Meng, and Y. Hu, "Experimental research of an all-polarization-maintaining optical fiber vector hydrophone,"

*Journal of Lightwave Technology*, 2012, 30(8): 1178–1184.

[81] C. Peng, X. Zhang, and Z. Meng, "Bearing estimation for optical fiber vector hydrophone with in-band resonance," *Applied Acoustics*, 2020, 158: 107055-1–107055-7.

[82] P. Nash, A. Strudley, R. Crickmore, and J. Defreitas, "High efficiency TDM/WDM architectures for seismic reservoir monitoring," in *Proceedings of 20th International Conference on Optical Fibre Sensors*, Edinburgh, UK, 2009, pp. 75037T.

[83] J. T. Kringlebotn, H. Nakstad, and M. Eriksrud, "Fibre optic ocean bottom seismic cable system: from innovation to commercial success," in *Proceedings of 20th International Conference on Optical Fibre Sensors*, Edinburgh, UK, 2009, pp. 75037U.

[84] F. Roar, "A fibre optic accelerometer and a method of manufacturing a fibre optic accelerometer," Europe Patent EP2369352, December 19, 2012.

[85] T. Chang, Z. Wang, Y. Yang, Y. Zhang, Z. Zheng, L. Cheng, *et al.*, "Fiber optic interferometric seismometer with phase feedback control," *Optics Express*, 2020, 28(5): 6102–6122.

[86] Y. Yang, Z. Wang, T. Chang, M. Yu, J. Chen, G. Zheng, *et al.*, "Seismic observation and analysis based on three-component fiber optic seismometer," *IEEE Access*, 2020, 8: 1374–1382.

[87] J. Chen, T. Chang, Q. Fu, J. Lang, W. Gao, Z. Wang, *et al.*, "A fiber-optic interferometric tri-component geophone for ocean floor seismic monitoring," *Sensors*, 2017, 17(1): 47.

[88] G. A. Cranch and P. J. Nash, "High-responsivity fiber-optic flexural disk accelerometers," *Journal of Lightwave Technology*, 2000, 18(9): 1233–1243.

[89] P. Jackson, S. Foster, and S. Goodman, "A fibre laser acoustic vector sensor," in *Proceedings of 20th International Conference on Optical Fibre Sensors*, Edinburgh, UK, 2009, pp. 750329.

[90] G. A. Cranch, G. A. Miller, and C. K. Kirkendall, "Fiber laser sensors: enabling the next generation of miniaturized, wideband marine sensors," in *Proceedings of Fiber Optic Sensors and Applications VIII*, United States, 2011, pp. 80280I.

[91] S. B. Foster, G. A. Cranch, J. Harrison, A. E. Tikhomirov, and G. A. Miller, "Distributed feedback fiber laser strain sensor technology," *Journal of Lightwave Technology*, 2017, 35(16): 3514–3530.

[92] M. Jin, H. Ge, D. Li, and C. Ni, "Three-component homovibrational vector hydrophone based on fiber Bragg grating F-P interferometry," *Applied Optics*, 2018, 57(30): 9195–9202.

[93] X. Zhang, F. Zhang, S. Jiang, L. Min, M. Li, G. Peng, *et al.*, "Short cavity DFB fiber laser based vector hydrophone for low frequency signal detection," *Photonic Sensors*, 2017, 7(4): 325–328.

[94] G. A. Cranch, G. A. Miller, and C. K. Kirkendall, "Fiber-optic, cantilever-type acoustic motion velocity hydrophone," *Journal of the Acoustical Society of America*, 2012, 132 (1): 103–114.

[95] G. A. Cranch, J. E. Lane, G. A. Miller, and J. W. Lou, "Low frequency driven oscillations of cantilevers in viscous fluids at very low Reynolds number," *Journal of Applied Physics*, 2013, 113(19): 194904.

[96] J. W. Lou, G. A. Cranch, G. A. Miller, and C. K. Kirkendall, "Miniaturization of acoustic vector sensors enabled by viscous fluids: Towards fiber laser hair sensors," in *Proceedings of Sensors, 2013 IEEE*, Baltimore, USA, 2013.

[97] J. H. Cole, J. A. Bucaro, C. K. Kirkendall, and A. Dandridge, "The origin, history and future of fiber-optic interferometric acoustic sensors for US Navy applications," in *Proceedings of 21st International Conference on Optical Fibre Sensors*, Ottawa, Canada, 2011, pp. 775303.

[98] F. Souto, "Fibre optic towed array: The high tech compact solution for naval warfare," in *Proceedings of Acoustics 2013*, Victor Harbor, Australia, 2013.

[99] R. Rajesh, C. Sreehari, K. Vivek, S. S. Kumar, T. Praveen, S. V. Pereira, *et al.*, "An eight element hydrophone array using DFB fiber laser with bender bar packaging," in *Proceedings of 13th International Conference on Fiber Optics and Photonics*, Kanpur, India, 2016, pp. Th3A.52.

[100] H. Zhang, X. W, and C Zhao, "Sea trial of 16-element DFB-FL hydrophone towed array," in *Proceedings of Applied Optics and Photonics China (AOPC2019)*, Beijing, China, 2019, pp. 1134016.

[101] C. Peng and X. Zhang, "A dynamic depth estimation method for towed optical fiber hydrophone array," *The Journal of the Acoustical Society of America*, 2018, 143(5): EL399–EL404.

[102] Z. Zheng, T. C. Yang, P. Gerstoft, and X. Pan, "Joint towed array shape and direction of arrivals estimation using sparse Bayesian learning during maneuvering," *The Journal of the Acoustical Society of America*, 2020, 147(3): 1738-1751.

[103] G. Wang, F. Liu, Y. Shi, and Y. Yi, "A method for estimating the shape of towed array based on genetic algorithm," in *Proceedings of IEEE International Conference on Signal Processing, Communications and Computing,* Xiamen, China, 2017, pp: 1–4.

[104] J. L. Odom and J. L. Krolik, "Passive Towed Array Shape Estimation Using Heading and Acoustic Data", *IEEE Journal of Oceanic Engineering,* 2015, 40(2): 465–474.

[105] H. Martins, M. B. Marques, and O. Frazo, "300 km-ultralong Raman fiber lasers using a distributed mirror for sensing applications," *Optics Express*, 2011, 19(19): 18149–18154.

[106] X. Jia, Y. Rao, C. Yuan, J. Li, X. Yan, Z. Wang, *et al.*, "Hybrid distributed Raman amplification combining random fiber laser based 2nd-order and low-noise LD based 1st-order pumping," *Optics Express*, 2013, 21(21): 24611–24619.

[107] S. Olsson, H. Eliasson, E. Astra, M. Karlsson, and P. A. Andrekson. "Long-haul optical transmission link using low-noise phase-sensitive amplifiers," *Nature Communications*, 2018, 9(1): 2513.

[108] P. Rosa, G. Rizzelli, X. Pang, O. Ozolins, A. Udalcovs, M, Tan, *et al.*, G. Jacobsen, S. Popov, and J. D. Ania-Castañón, "Unrepeatered 240-km 64-QAM transmission using distributed Raman amplification over SMF fiber," *Applied Sciences*, 2020, 10(4): 1433

[109] Y.Fu, Y. Rao, R. Zhu, Z. Wang, B. Han, H. Wu, and C. Lu, "175km repeaterless BOTDA with hybrid 2nd- and 3rd-order Raman random fiber laser amplification," in *Proceedings of 26th International Conference on Optical Fiber Sensors,* Lausanne Switzerland, 2018, pp. TuD2

[110] C. Cao, S. Xiong, Q. Yao, Z. Hu, and Y. Hu, "Performance of a 400km interrogated fiber optics hydrophone array," in *Proceedings of 23rd International Conference on Optical Fiber Sensors*, Santander, Spain, 2014, pp. 91579B.

[111] W. Chen and Z. Meng, "Intensity and phase noise caused by stimulated Brillouin scattering," in *Proceedings of 21st International Conference on Optical Fibre Sensors*, Ottawa, Canada, 2011, pp. 77532G.

[112] G. P. Agrawal, *Nonlinear fiber optics*. Beijing: Publishing House of Electronics Industry, 2002.

[113] A. Hirose, Y. Takushima, and T. Okoshi, "Suppression of stimulated Brillouin scattering and Brillouin crosstalk by frequency-sweeping spread-spectrum scheme," *Journal of Optical Communications*, 1991, 12(3): 82–85.

[114] N. Yoshizawa and T. Imai, "Stimulated Brillouin scattering suppression by means of applying strain distribution to fiber with cabling," *Journal of Lightwave Technology*, 1993, 11(10): 1518–1522.

[115] F. W. Willems, W. Muys, and J. S. Leong, "Simultaneous suppression of stimulated Brillouin scattering and interferometric noise in externally modulated lightwave AM-SCM systems," *IEEE Photonics Technology Letters*, 1994, 6(12): 1476–1478.

[116] P. T. Dinda, G. Millot, and P. Louis, "Simultaneous achievement of suppression of modulational instability and reduction of stimulated Raman scattering in optical fibers by orthogonal polarization pumping," *Journal of Optical Society of America B*, 2000, 17(10): 699–701.

[117] W. Chen and Z. Meng, "Effects of phase modulation used for SBS suppression on phase noise in an optical fibre," *Journal of Physics B: Atomic, Molecular and Optical Physics*, 2011, 44(16): 165402.

[118] W. Du, P. Zhou, Y. Ma, X. Wang, J. Zhu, X. Dong, *et al.*, "Experimental study of SBS suppression with phase-modulation in all-fiber amplifier," in *Proceedings of International Symposium on Photoelectronic Detection and Imaging 2011*, Beijing, China, 2011, pp. 81921C.

[119] J. O. White, A. Vasilyev, J. P. Cahill, N. Satyan, and O. Okusaga, "Suppression of stimulated Brillouin scattering in optical fibers using a linearly chirped diode laser," *Optics Express*, 2012, 20(14): 15872–15881.

[120] W. Chen and Z. Meng, "Effects of phase modulation on threshold of stimulated Brillouin scattering in optical fibers," *Chinese Journal of Lasers*, 2011, 38(3): 140–143 (in Chinese).

[121] X. Hu, W. Chen, X. Tu, and Z. Meng, "Theoretical and experimental study of suppressing stimulated Brillouin scattering and phase noise in interferometric fiber sensing systems with phase modulation," *Applied Optics*, 2015, 54(8): 2018–2022.

[122] X. Hu, W. Chen, S. Sun, Y. Lu, and Z. Meng, "The effect of modulation instability on the interferometric fiber sensing systems," in *Proceedings of Opt-Electronics and communications Conference (OECC) and Photonics Global Conference (PGC)*, Singapore, 2017.

[123] M. A. Soto, M. Alem, W. Chen, L. Thévenaz, and L. R. Jaroszewicz, "Mitigating modulation instability in Brillouin distributed fibre sensors," in *Proceedings of Fifth European Workshop on Optical Fibre Sensors*, Krakow, Poland, 2013, pp. 87943J.

[124] J. Urricelqui, M. Alem, M. Sagues, L. Thévenaz, A. Loayssa, and M. A. Soto, "Mitigation of modulation instability in Brillouin distributed fiber sensors by using orthogonal polarization pulses," in *Proceedings of 24th International Conference on Optical Fibre Sensors*, Brazil, 2015, pp. 963433.

[125] M. A. Soto, A. L. Ricchiuti, L. Zhang, D. Barrera, S. Sales, and L. Thévenaz, "Time and frequency pump-probe multiplexing to enhance the signal response of Brillouin optical time-domain analyzers," *Optics Express*, 2014, 22(23): 28584–28595.

[126] X. Hu, W. Chen, Y. Lu, M. Chen, and Z. Meng, "Suppression of spontaneous modulation instability and phase noise with a coherent seed in the interferometric fiber sensing systems," *Optics Letters*, 2018, 34(15): 3642–3645.