

## Optical ultrasonic imaging of geological structure models

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### 1 INTRODUCTION & AIM

Seismic physical modeling is employed to promote the exploitation of oil and gas resources with lower cost and better controllability in laboratory [1]. Geological structure models are seismic physical models (SPMs) constructed based on earth structures and formations according to specific similarity ratios.

Ultrasonic or laser-ultrasonic techniques are utilized to perform SPM imaging and piezoelectric transducers (PZTs) have been extensively utilized. Relatively, optical ultrasonic emitters and detectors have emerged as a mainstream trend, providing enhanced broadband transmit-receive capabilities [2].

Over past decade, our group has focused on the development of optical ultrasonics and advanced the optical transceiving method in comparison with its electrical counterparts, aiming to improve the microstructure recognition performance of the SPM imaging platform [3].

### 2 METHOD & SYSTEM

#### Process flow of seismic physical modeling

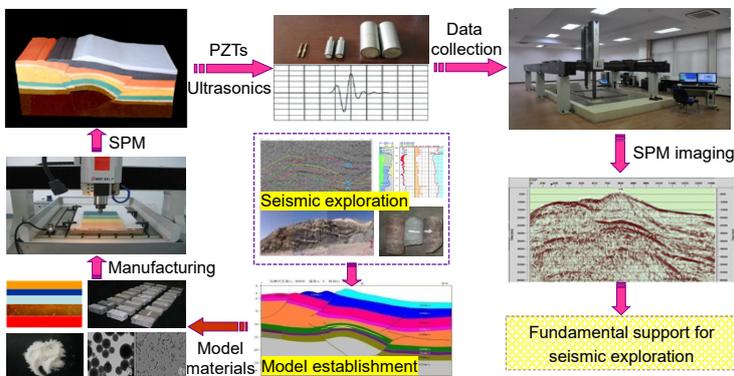


Figure 1. Seismic physical modeling is a forward modeling method in laboratory that involves creating physical models of field geological structures according to a certain similarity ratio.

#### In-lab platform of optical-ultrasound modeling

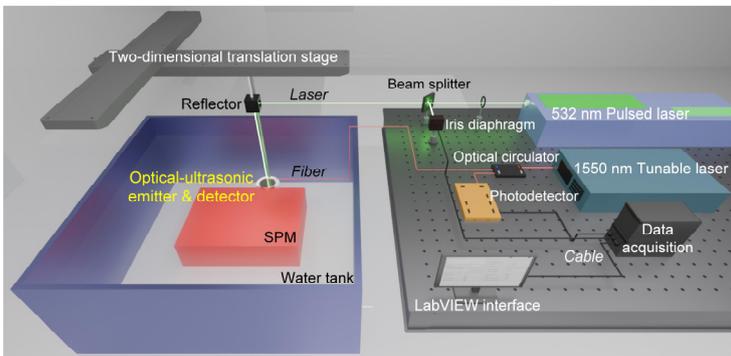


Figure 2. The experimental setup for optical seismic physical modeling consists of three components: laser ultrasound excitation using the optoacoustic transducer, ultrasound propagation within the SPM, and echo detection through the fiber-optic sensor.

#### REFERENCES

- [1] Yin H, Shao Z, Chen F, et al. Journal of Lightwave Technology, 2022, 40(15): 5294-5299.
- [2] Cao X, Yang H, Wang M, et al. Light: Science & Applications, 2026, 15(1): 171.
- [3] Yin H, Shao Z, Qiao X. Ultrasonics, 2025, 152: 107634.

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### 3 RESULTS & DISCUSSION

#### Ultrasound emitter : Laser excitation of the composite material

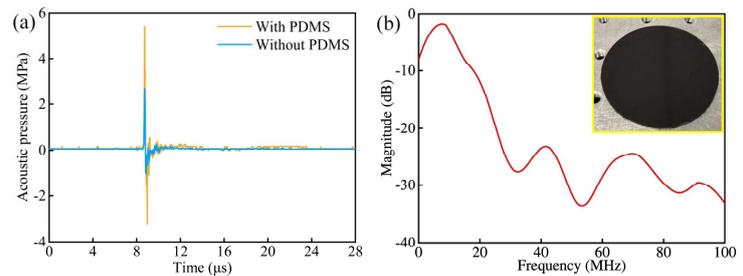


Figure 3. Optoacoustic measurements of the composite material (a) comparison between the single  $Ti_3C_2$  material and the  $Ti_3C_2$ -PDMS composite structure, (b) frequency-domain curve of the composite material (the inset shows the prepared optoacoustic material film).

#### Ultrasound sensor : Ultrasonic testing of the fiber-optic sensor

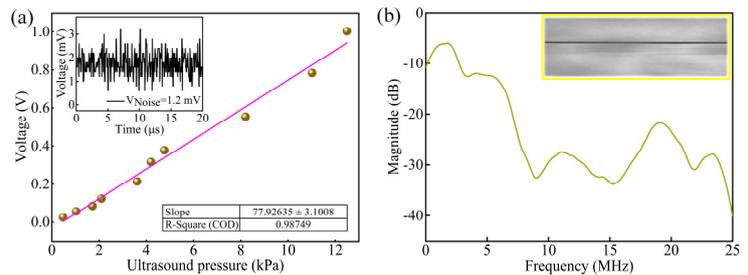


Figure 4. Acoustic measurements of the fiber-optic sensor (a) ultrasonic sensitivity (at a low noise equivalent pressure range of the 10 Pa level), (b) frequency response curve (the inset shows the micrograph of the fiber Bragg grating located at the core).

#### Ultrasound imaging : Scan and reconstruction of the 3D SPM

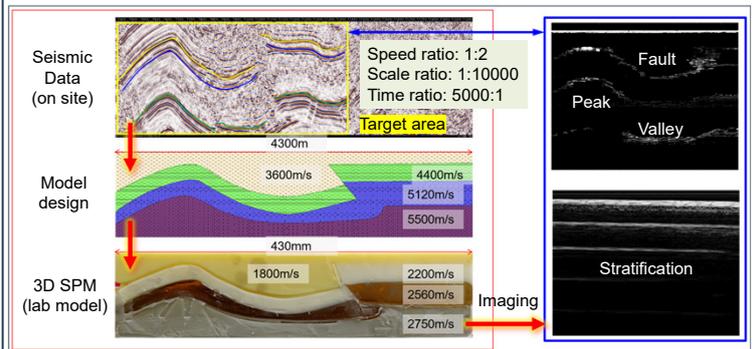


Figure 5. Optical-ultrasound imaging of a layered planar SPM. The research process is presented in the form of "on site – lab model – on site". The SPMs are imaged to refine the understanding of complex geological sections, thereby improving the accuracy of reservoir interpretation.

### 4 CONCLUSIONS

- The high-efficiency transducer and the high-sensitivity sensor are integrated to achieve optical ultrasonic imaging of SPM with an enhanced signal-to-noise ratio.
- This advanced optical ultrasound transceivers present a novel methodology in optical ultrasonics that is well-suited for structural and tissue imaging applications.