Overcoming the VUV Bottleneck: A New High-Performance Nonlinear Optical Crystal

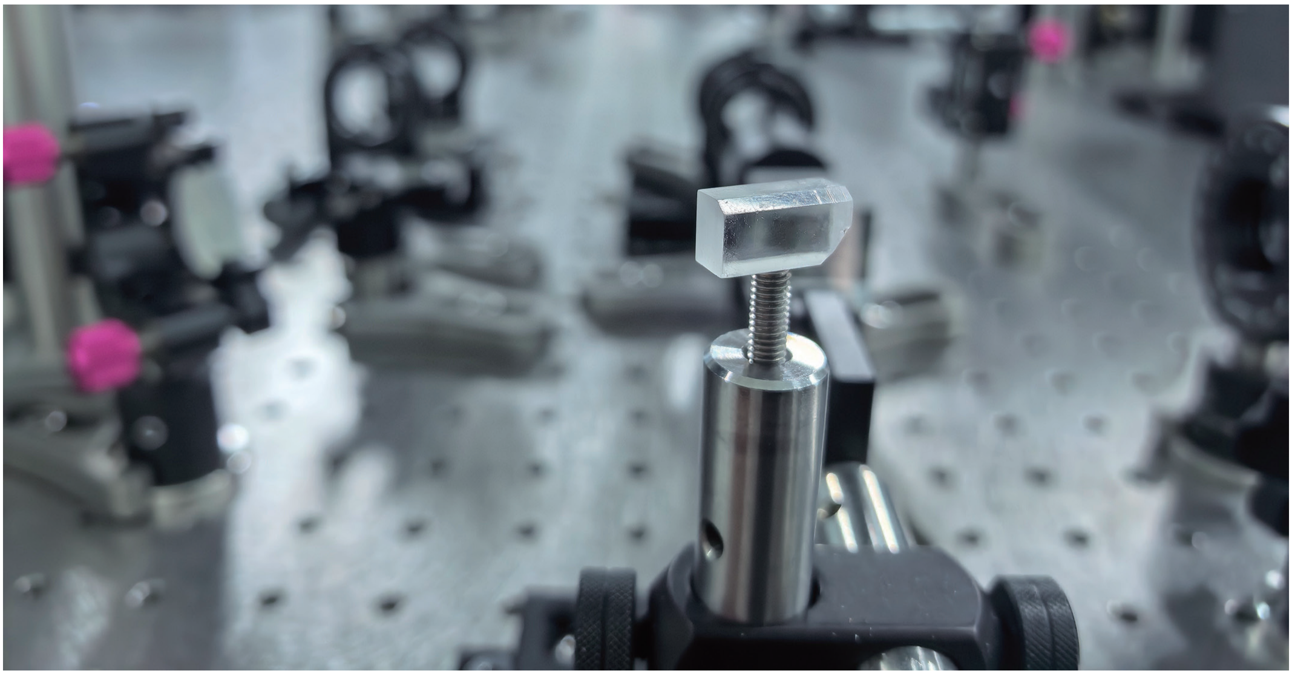
Vacuum ultraviolet (VUV, 100–200 nm) light sources are indispensable for advanced spectroscopy, quantum research, and semiconductor lithography. Although second harmonic generation (SHG) using nonlinear optical (NLO) crystals is one of the simplest and most efficient methods for generating VUV light, the scarcity of suitable NLO crystals has long been a bottleneck.

To address this problem, a research team led by Prof. PAN Shilie at the Xinjiang Technical Institute of Physics and Chemistry (XTIPC) of the Chinese Academy of Sciences (CAS) has developed the fluorooxoborate crystal $NH_4B_4O_6F$ (ABF)—offering an effective solution to the practical challenges of VUV NLO materials. The team's findings were published in *Nature* (doi: 10.1038/s41586-025-10007-z) on January 28.

The team's key achievement is the growth of centimeter-scale, high-quality ABF crystals and the development of advanced anisotropic crystal processing technologies. Notably, ABF uniquely integrates a set of conflicting yet critical properties required for VUV NLO materials—excellent VUV transparency, a strong NLO coefficient, and substantial birefringence for VUV phase-matching—while fulfilling stringent practical criteria: large crystal size for fabricating devices with specific phase-matching angles, stable physical/chemical properties, a high laser-induced damage threshold, and suitable processability. This breakthrough resolves a long-standing challenge in the field, as no prior crystal has met all these criteria simultaneously.

As a specialized optical crystal, ABF achieves a notable feat by generating VUV light down to 158.9 nm through SHG. This

ABF Angle-Phase-Matched VUV SHG Device. (Image by Prof. PAN Shilie's team)



Laser output demonstration. (Image by Prof. PAN Shilie's team)

shorter wavelength opens new avenues for scientific exploration in fields including superconductivity research and chemical reaction studies.

Specifically, its wavelength conversion capability enables the generation of high-energy VUV light, with a maximum nanosecond pulse energy of 4.8 mJ at 177.3 nm and a conversion efficiency of 5.9%. These values set a new record, representing the highest nanosecond pulse energy and conversion efficiency ever reported for VUV SHG devices, the researchers noted. They added that further improvements in output energy and conversion efficiency are anticipated in future work through enhancements in crystal quality and device fabrication precision.

The promising performance of the ABF crystal stems from its unique structure: By incorporating fluorine into the borate system, the researchers constructed fluorooxoborate groups and regulated their arrangement, markedly enhancing the crystal's overall performance. This design strategy provides a viable approach for exploring VUV NLO materials.

The development of ABF paves the way for compact, efficient all-solid-state VUV lasers. This advancement is expected to improve access to VUV light in both scientific research and industrial applications, driving progress in areas such as advanced chip manufacturing and cutting-edge scientific investigations.

(Source: XTIPC)