Supplemental Document

Optics EXPRESS

DUV coherent light emission from ultracompact microcavity wavelength conversion device: supplement

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A. Detail of optical experimental setup

Figure S1(a) shows a schematic of the optical experiment setup. The SHG device was excited by a picosecond Ti:sapphire regenerative amplifier (Spectra Physics, Spitfire Pro) and an optical parametric oscillator (OPO) system (Light Conversion, TOPAS) with a spectral FWHM of 0.6 nm and a repetition rate of 1 kHz. The polarization of the fundamental wave was controlled by a Glan–Thompson prism (Thorlabs, GLB10) and a half-wave plate (Thorlabs, AHWP05M-600). The fundamental wave was focused on the SHG device by an objective lens (Nikon, TU PLAN EPI 20X) with a long working distance of 19 mm through a laboratory-made dichroic mirror that selectively reflects UV light with wavelengths between ~220 nm and ~260 nm. The transmission spectrum of the dichroic mirror at 45° incidence is shown in Fig. S1(b). The generated far-UV SH wave was reflected in a 45° direction by the dichroic mirror. The SH wave enters the optical fiber (Thorlabs, M114L01) through a bandpass filter (Asahi spectra, LX0248 HQBP248-UV) with >10% transmittance at 222–262 nm and >3.5 optical density in the blocking band at 400–500 nm and a focusing lens (Sigma Koki, SLSQ-15-20P). The SH wave emitted from the optical fiber passes through a collimating lens (Sigma Koki, SLSQ-25-60P) and a focusing lens (Sigma Koki, SLSQ-25-80P), and enters the spectrometer (Princeton Instruments, SP2500 with Princeton Instruments, PIXIS).

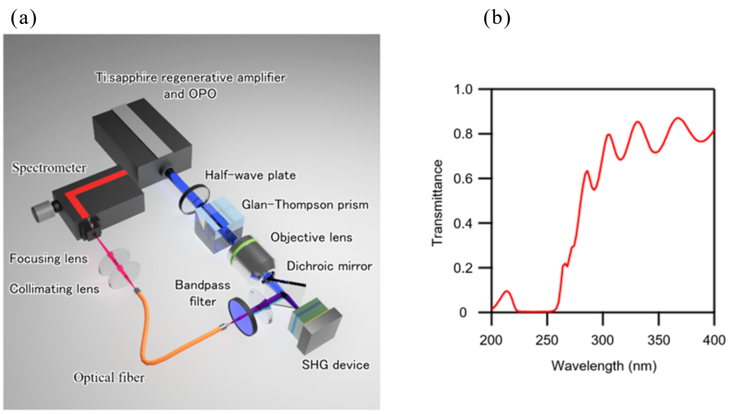

Fig. S1. Detail of optical experiment setup. (a) Schematic of optical experiment setup. (b) Transmission spectra. at 45° incidence of laboratory-made dichroic mirror.

B. Polarization characteristics of SHG

Since SBO is a crystal belonging to the 2*mm* point group, the second-order nonlinear optical tensor ***d*** has the forms

$$\boldsymbol{d} = \begin{bmatrix} 0 & 0 & 0 & 0 & d_{15} & 0 \\ 0 & 0 & 0 & d_{24} & 0 & 0 \\ d_{31} & d_{32} & d_{33} & 0 & 0 & 0 \end{bmatrix}, \tag{S1}$$

where *d* is a second-order nonlinear optical tensor component. Thus, the complex polarization vector of the SH wave $\boldsymbol{P}^{2\omega}$ has the forms

$$\boldsymbol{P}^{2\omega} = \begin{bmatrix} P_x^{2\omega} \\ P_y^{2\omega} \\ P_z^{2\omega} \end{bmatrix} = \varepsilon_0 \begin{bmatrix} 2d_{15}E_z^{\omega}E_x^{\omega} \\ 2d_{24}E_y^{\omega}E_z^{\omega} \\ d_{31}(E_x^{\omega})^2 + d_{32}\left(E_y^{\omega}\right)^2 + d_{33}(E_z^{\omega})^2 \end{bmatrix}, \tag{S2}$$

where $\boldsymbol{P}^{2\omega}$ is the complex polarization vector component of the SH wave and E^{ω} is the complex electric field amplitude vector component of the fundamental wave [1]. Equation (S2) shows that the extraordinary SH waves are generated by the excitation of both ordinary and extraordinary fundamental waves. Since d_{33} and d_{31} of the SBO crystal are 3.5 pm/V and 1.7 pm/V, respectively, the SH wave generated by the extraordinary fundamental wave should be ~4.2 times larger than that generated by the ordinary fundamental wave [2].

We added another Glan–Thompson prism between the short-pass filter and the optical fiber shown in Fig. S1(a), and investigated the polarization characteristics by turning the two Glan–Thompson prisms independently. Figure 5(d) shows that an extraordinary SH wave was generated when the SHG device was excited by the extraordinary fundamental wave. This result indicates that SHG via the second-order nonlinear optical tensor component of d_{33} was achieved. Figure S2 shows that the extraordinary SH wave was generated under excitation by the ordinary fundamental wave. This result indicates that SHG via the second-order nonlinear optical tensor component of d_{31} was achieved. These results are consistent with Equation (S2). The counts of the spectrometer for the SH wave generated by the extraordinary fundamental wave was about ~36 times larger than that for the SH wave generated by ordinary fundamental wave. Although the effect of optical path deviation was superimposed, this result can be explained by each *d* value and the sharpness of the resonance.

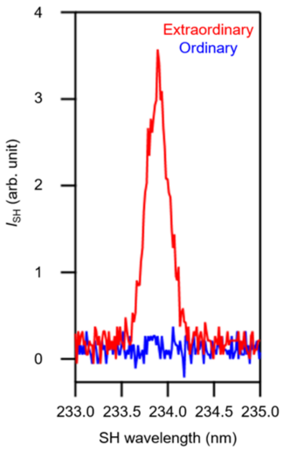

Fig. S2. Spectra of extraordinary and ordinary SH waves pumped by ordinary fundamental wave.

References

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