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High Average-Power and Energy Deep-Ultraviolet Femtosecond Pulse Source Driven by 10 MHz Fibre-Laser

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Fibre lasers have created a revolution in ultrafast pulse sources, due to their high average-power and high repetition-rates, with commercial 300 fs pulse systems routinely delivering > 20 µJ and > 20 W. However, apart from discreet harmonic schemes, short-wavelength frequency tunability is lacking, and producing shorter pulse durations requires additional compression stages. Gas-filled, hollow-core kagomé photonic-crystal fibres (kagomé-PCF) are ideal nonlinear compressors for these systems [1], and have enabled the generation of < 10 fs pulses with 18 W average power [2]. Here we show that they can additionally be used to generate up to 70 nJ deep-UV pulses, tunable between at least 270 nm to 320 nm, at high repetition-rate, and hence average-power—exceeding 693 mW. This unique source will have a wide range of applications, to for example, angle-resolved photoemission spectroscopy [3] or ultrafast pump-probe measurements of biological molecules.

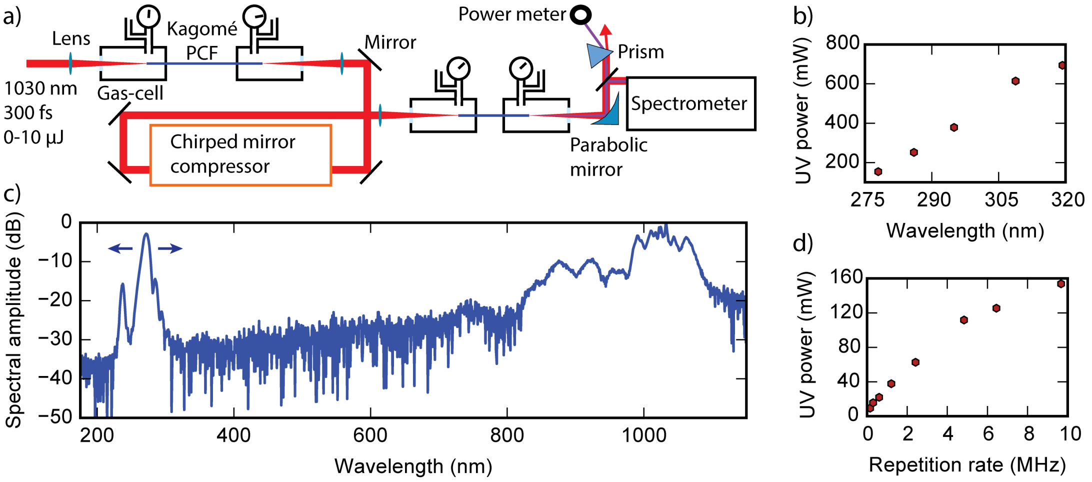

Fig. 1 (a) The experimental set-up; (b) average deep-UV power for each pressure-tuned wavelength at 9.6 MHz; (c) example output spectrum of the second stage when pressure tuned to produce 278 nm; (d) corresponding average power scaling at 278 nm with repetition rate.

The experimental setup, depicted in Fig. 1(a), consists of two kagomé-PCF stages. The output of our 1030 nm, 300 fs fibre laser is compressed to ~25 fs through self-phase-modulation-based spectral broadening in a kagomé-PCF filled with a 0 to 32 bar krypton pressure gradient, and subsequent phase-compensation with chirped mirrors. The compressed pulses are launched into a second kagomé-PCF filled with 10 bar Ar to generate UV radiation through dispersive-wave (DW) emission [4]. By tuning the gas pressure in the second stage, and hence phase-matching conditions, the DW could be tuned, as shown in Fig. 1(b). The deep-UV power at 9.6 MHz ranges from 153 mW at 278 nm, up to 693 mW at 320 nm. For the 278 nm case the full spectrum is shown in Fig. 1(c). The deep-UV peak is broadband, ~10 nm, and numerical simulations, rigorously validated in previous work [4], predict the pulse duration of the deep-UV light to be < 20 fs. Fig. 1(d) shows how the average-power at 278 nm scales with repetition rate. The change in slope around 6 MHz is due to the onset of plasma build-up inside the fibre. This is supported by observations of side-scattered recombination luminescence (not shown), and numerical simulations.

Using lighter gases in the second stage should avoid the plasma build-up, enabling further power scaling and the generation of shorter wavelengths. Vacuum-ultraviolet DWs, down to 120 nm, were recently generated in a helium-filled kagomé-PCF system using a 1 kHz, 800 nm, Ti:sapphire laser [5]. The results shown here raise the prospect of creating a fibre-laser pumped Watt-level VUV pulse source.

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