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A fiber-CPA laser system using nonlinear-PCF compression for intra-cavity high harmonics generation at 10 MHz repetition rate

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Introduction: Now-days, enhancement cavity (EC) based high harmonics generation (HHG) has been viewed as a promising method for achieving high repetition rate (>10 MHz) VUV laser source [1], which can find applications in photoelectron spectroscopy and frequency comb metrology. However, the frequently-used seed for EC, high power Yb^{3+}-based fiber CPA laser system, is not satisfactory in terms of its gain bandwidth limited ~200 fs pulse duration, with which significant ionization of the HHG-medium deteriorates the effective peak intensity. Nonlinear pulse compression using large core PCF could be an effective way for circumventing the problem.

Experiment, results & discussion: Fig. 1 shows the entire experimental schematic diagram. The laser system used here is a 10MHz Yb^{3+}-based fiber CPA laser system, whose pulse duration is ~200 fs [2]. For broadening the spectrum, we adopted a piece of PCF (Thorlabs: LMA35), 2cm in length. To avoid damage by self-focusing in the fiber, a quarter-wave-plate is used for converting the original linear polarization to circular polarization. By careful adjustment, more than 80% coupling efficiency and good transverse mode have been achieved when the input power is 15W, shown in figure 2. Then, the laser is guided to a pair of gratings with groove density of 1250l/mm for dispersion compensation. The distance between the two gratings is adjusted to be around 0.5mm for shortest pulse width, which is verified to be ~60 fs by FROG. With this short pulse laser and original long pulse laser as seed for EC, we conduct intra-cavity high harmonics experiment respectively and compare the results [3], shown in figure 3. It is obvious that higher order high harmonics have been generated with short pulse. Single-crystal MgO plate is installed inside the external cavity that works as a dichroic mirror to couple out high harmonic radiation from the cavity. With reflectivity-enhanced-coating on the MgO, we can couple out more than 0.1 mW at the wavelength of 147nm (7th harmonic). Intra-cavity powers of 0.3 kW and 0.7 kW are obtained for short pulse and long pulse. Lower intra-cavity power for short pulse is partly due to reduced seeding power for the EC and partly due to less efficient longitudinal mode-matching to the cavity with degraded beam profile. Even so, as far as high harmonics yields are concerned, they are comparable for long and short pulses. Therefore, higher harmonics power could be expected by increasing the short pulse power and improving its coupling to the EC. Presently, chirped pulse compression is under consideration for getting higher power [4].

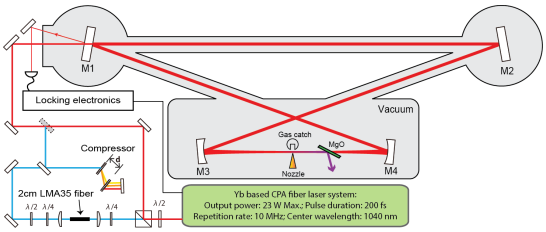

Fig. 1 Schematic diagram.

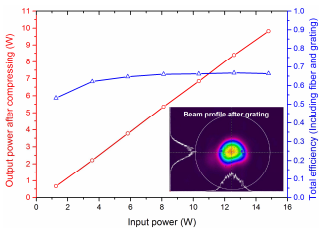

Fig.2 PCF performance.

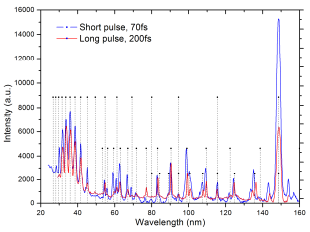

Fig. 3 HHG results.

Conclusion: PCF based nonlinear compression is an effective way for obtaining high power shorter pulse seed laser for seeding enhancement cavity. Harmonics with higher order have been generated with this shorter pulse laser source.

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[3] A. Ozawa, CLEO, CM3N.2 (2013); [4] T. Ganz, OL, **36** 1107 (2011)