3P077

Ultrashort laser shaping for scanning near-field optical microscopy

(Institute for Molecular Science,[a] The Graduate University for Advanced Studies,[b] Waseda University [c]) ○Yuqiang Jiang,[a] Huijun Wu,[a] Tetsuya Narushima,[a,b] Kohei Imura,[c] Hiromi Okamoto,[a,b]

[Introduction] Scanning near-field optical microscopy with ultrashort laser pulses would be a highly potential method to detect ultrafast dynamics with ultrahigh spatial resolution. However, the laser pulses after passing through a near-field probe made of optical fiber is seriously broadened due to the group velocity dispersion in the fiber. In this work, by using the Fourier synthesis techniques with a programmable phase modulator, we tried to recover femtosecond laser pulses which were broadened by the optical fiber used for the near-field probe.

[Experimental] The most successful techniques for ultrashort laser pulse shaping involve Fourier synthesis, where the optical field is modified by modulation of its spatially dispersed frequency components. In our work, a programmable phase modulator (PPM, X8267, Hamamatsu) was used as the spatial modulator. The schematic diagram of the experimental setup is shown in Figure 1. In this setup, we have installed a simple single-mode optical fiber to examine the system performance, but the fiber will be replaced by a near-field probe in the future for practical near-field experiments. The femtosecond laser pulses were dispersed by a grating. The dispersed frequency components were collimated by a concave cylindrical mirror (CCM), and introduced to the PPM that is located on the focal plane of the CCM. The frequency components were modulated by PPM, converged again by the CCM to the grating, and then collinearly combined by the grating as a single beam. The beam was focused on a BBO crystal after passing through an optical fiber. The SHG radiation emitted from the BBO crystal was detected by a photomultiplier tube (PMT), and its intensity was used as the feedback signal to control the PPM.

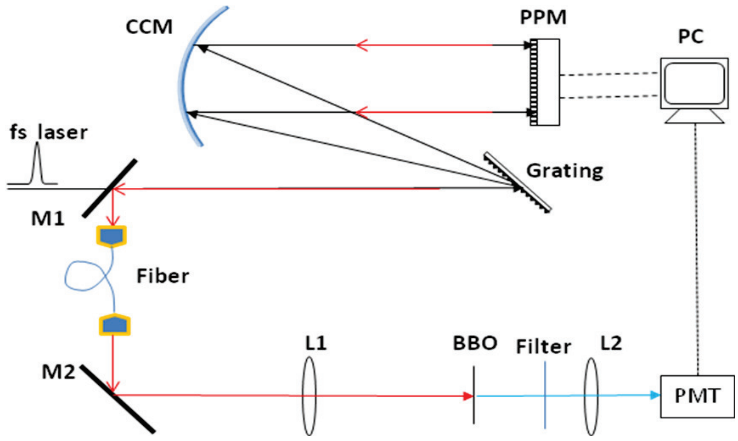

Figure 1. The schematic diagram of experimental setup.

One prominent merit of PPM is its high spatial resolution of modulation. It consists of 590,000 pixels within a 20×20 mm^2 area; each of those can be individually controlled. The phase shift of each pixel is controlled by the brightness signal output from a PC. For incident light of 800-nm wavelength, the maximum of phase shift is more than 4π rad. As the laser beam was dispersed horizontally, the modulation of PPM to the laser beam can be controlled by a series of vertical gray bars. A simulated annealing algorithm (SAA) was employed to produce intensity terns of the bars and to seek for the best tion (a set of bars), that generates the highest SHG signal. A Ti:sapphire femtosecond laser (MaiTai, Spectra Physics) was used as the source of femtosecond pulses. Its pulsewidth was about 90 fs (autocorrelation width ~140 fs), and the wavelength was continuously tunable from 780 nm to 920 nm.

A typical result is shown in Figure 2. The 90-fs laser pulses were broadened by the fiber to a few picoseconds because of group velocity dispersion while propagating in the fiber (Fig. 2a). They were compressed by the PPM system to a few hundreds femtoseconds (Fig. 2b). Figures 2c and 2d show the pattern of the optimized brightness signal applied to PPM and the relative phase shift respectively, after compression of the laser pulses.

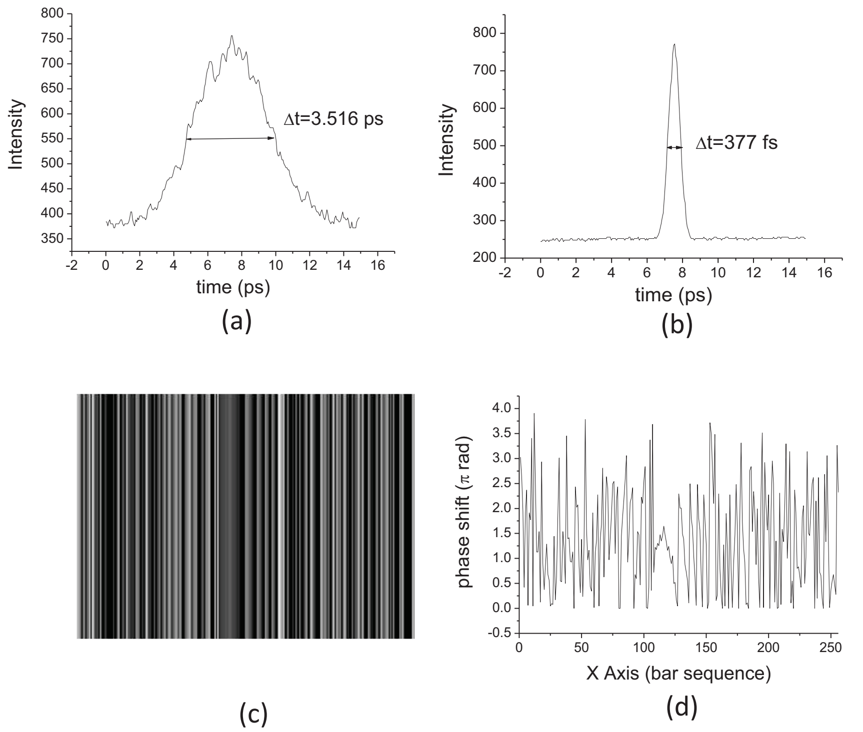

Figure 2. Compression of laser pulses broadened by an optical fiber (1 meter in length). (a) The laser pulses broadened to 3.516 ps by the fiber; (b) The laser pulses compressed to 377 fs by the PPM system; (c) The brightness pattern applied to PPM produced by SAA when laser pulses were compressed; (d) The phase shift generated by the PPM corresponding to the pattern (c).

[Discussion] When the optical fiber was absent, the dispersed laser pulses can be recovered to 100-fs level. We also tested the compression with a 20-fs laser source. The setup was also working well. With an optical fiber in the path, however, the results were not good as expected. This should derive from the following reason. The modulation capability of the PPM is limited. As mentioned above, the maxmium phase shift generated by the pixels of PPM is about 4π. On the other hand, the dispersion produced by the long (1-meter length) optical fiber is so large that it is out of the compensation range that the PPM can provide. Also some nonlinear effects when high power laser passing thought the fiber might increase the difficulties of the compression.