SUPERCONTINUUM GENERATION IN HIGHLY NONLINEAR OPTICAL FIBERS USING CR:FORSTERITE LASER

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Abstract – The investigation of spectrum broadening of $Cr^{4+}:Mg_2SiO_4$ (Cr:Forsterite, Cr:F) laser in highly nonlinear dispersion-shifted optical fibers (HNLF) are presented. Besides, the laser spectrum was broadened in a dispersion-decreasing highly nonlinear dispersion-shifted optical fiber (HNLF DDF). The first results on spectrum broadening of Cr:Forsterite laser in tapered HNLF with taper waist diameter of 2 mkm and length of 6 cm are presented.

Keywords: highly nonlinear fiber, femtosecond laser, supercontinuum generation

At present time there is a growing demand for high precision metrology in the optical domain for communications, navigation, fundamental physics etc. A recent breakthrough in the methods of precision measurements became possible due to the development of highly stable femtosecond lasers and introduction of special optical fibers (photonic crystal fibers, tapered fibers) for generation of broad spectrum. Most of this work has taken advantage of the highly–developed Ti:Sapphire laser with the spectrum broadened from 400 to 1200 nm. The development of femtosecond lasers operating at longer wavelengths is beneficial to cover a highly employed spectral range of 1 – 2 micron. Cr:Forsterite laser can be a suitable candidate. This laser emits at a wavelength of 1.2 – 1.3 μm and its spectrum can be broadened in a highly nonlinear fiber.

The cavity of a Cr:F laser had a Z-shaped configuration. The gain crystal was 17 mm long. A pair of SF6 prisms was used to control dispersion in the cavity. The Cr:F crystal was mounted in a brass holder whose temperature was maintained at 10^0 C and was pumped by a commercial 10 W 1.06 μm Yb-fiber laser. Stable, self-sustained generation of ultrafast optical pulses has been obtained with pulses as short as 40 fs. The corresponding spectrum was centered on 1260 nm and had a bandwidth of 40 nm at FWHM. The pulse repetition rate was 100 MHz and the average output power was up to 500 mW at 5.5 W of the absorbed pump power.

The approach to produce fibers with varying along length chromatic dispersion has been developed. This method performs a precise control of the fiber core diameter during the drawing. This technology became possible owing to digital signal processing used for the control of the drawing process. At present fibers with various dispersion functions can be produced. Dispersion variations from 15 to -5ps/nm/km in single-mode regime at 1550nm wavelength are possible, keeping the optical loss at the same level as for conventional fibers.

The technology allows fibers with a necessary length dependence of the diameter to be fabricated. During the drawing process information about the current diameter is processed by a computer and compared with the prearranged value. A control signal produced by the computer is passed to the drawing unit. Soft- and hardwares have been developed to obtain single-mode fibers with chromatic dispersion varying along length, the fiber length being in

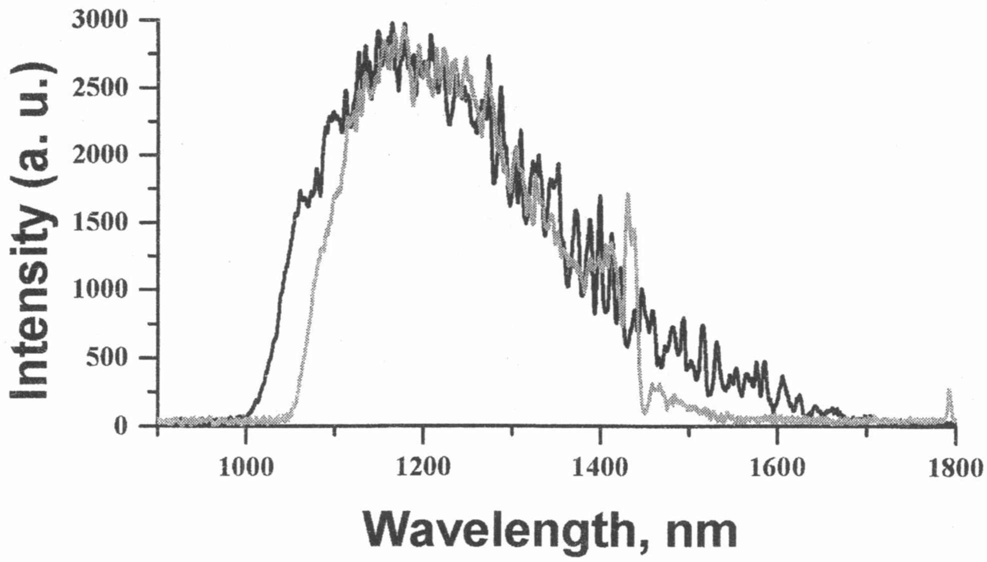

Fig. 1 – The spectrum broadening of Cr:Forsterite laser in HNLF fibers of 50 m length (black) and 30 m length (gray).

the range from several meters to several kilometers. The dispersion deviation from the prearranged value is less than 0.1ps/nmkm.

The three types of HNLF have been investigated. Fig. 1 represents the Cr:Forsterite laser spectrum broadened in HNLF with constant diameter of the fiber core. The HNLF is created by the modified chemical-vapor deposition of germanium and fluorine dopants on silica. The fibers had the length of 30 m (fiber cladding diameter is 116 mkm, core diameter is 4,76 mkm, cutoff wavelength is 1,1837 mkm) and 50 m (fiber cladding diameter is 107 mkm, core diameter is 4,09 mkm, cutoff wavelength is 1,1898 mkm). About ≈ 30 % of laser power was coupled into the fiber.

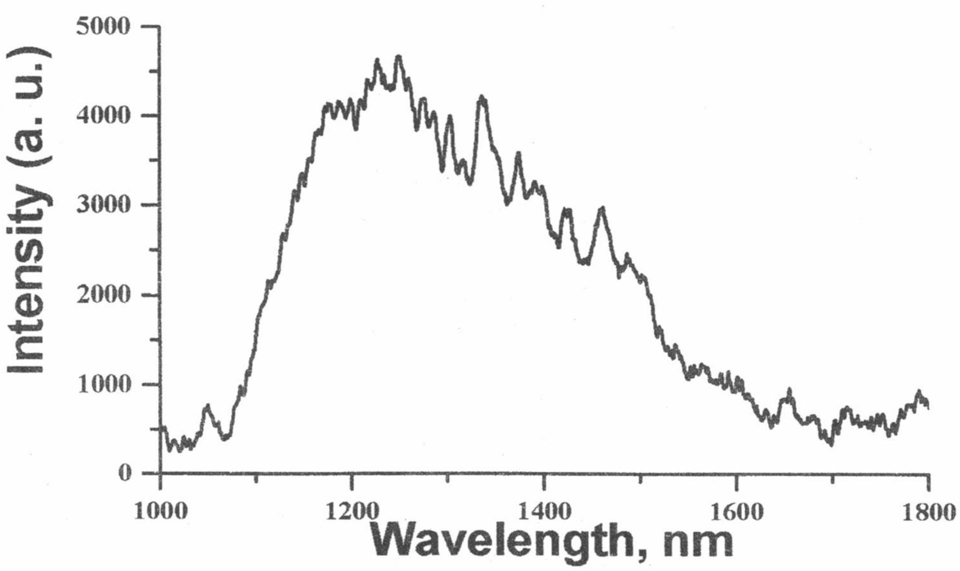

Fig. 2 – The spectrum broadening of Cr:Forsterite laser in tapered HNLF.

As can be seen from Fig. 1, the spectrum width increases with the fiber length insufficiently so one would need a fiber a few hundred meters long to reach 2 micron wavelength. A better solution would be to optimize the fiber's parameters such as dispersion. This can be done in a tapered fiber. Such HNLF tapered from the fiber with the core diameter of 4.29 μm, had the taper length of 60 mm and the taper waist diameter of 2 μm. The untapered sections at the input and output of the fiber were 50 mm and 100 mm respectively. The Cr:Forsterite laser spectrum broadened in this tapered fiber is shown in Fig. 2. The 60 mm-long tapered fiber can generate spectrum as wide as a much longer nontapered HNLF. We suggest that decreasing the taper waist to 1.5 μm will allow to broaden the spectrum from 1 to 2 μm.

Another way to manage the fiber dispersion is to use a dispersion-decreasing highly nonlinear dispersion-shifted optical fiber (HNLF DDF). Such fiber consists of a section with the conical core profile and two sections with the constant core diameter at the fiber extremes.

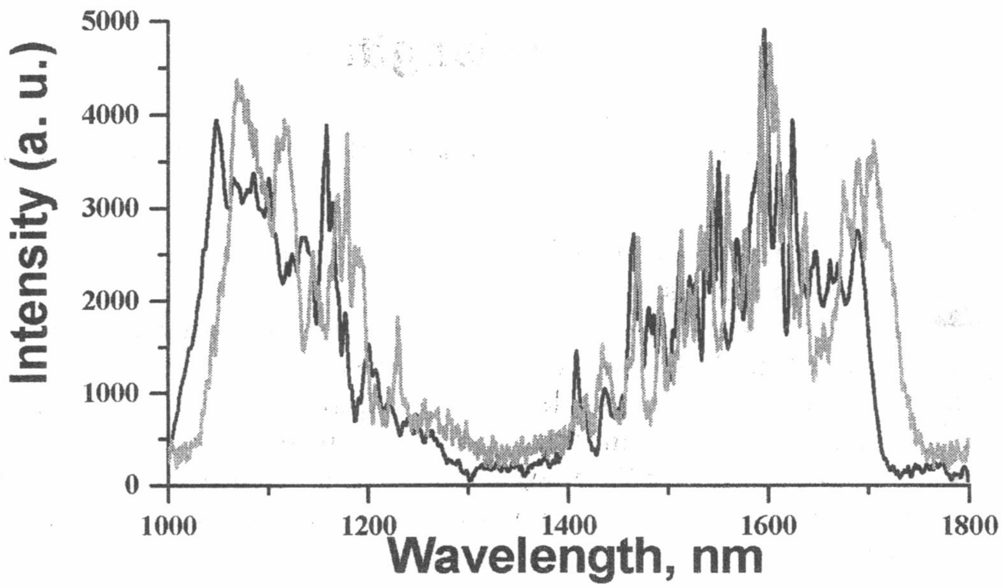

Fig. 3 – The spectrum broadening of Cr:Forsterite laser in HNLF DDF fibers of 5 m length (black) and 10 m length (gray).

The Cr:Forsterite laser spectra broadened in HNLF DDF are depicted in Fig. 3. One fiber had the conical section length of 5 m, fiber cladding diameter - 140 μm - 112.7 μm, dispersion of 12..-2 ps/nm*km at 1550 nm. Another fiber had the conical section length of 10 m, fiber cladding diameter – 133,6 μm - 112.7 μm, dispersion of 10..-2 ps/nm*km at 1550 nm.

In conclusion, the investigation of spectrum broadening of Cr:Forsterite laser in highly nonlinear dispersion-shifted optical fibers, in a dispersion-decreasing highly nonlinear dispersion-shifted optical fiber and in the tapered HNLF are presented.

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