Photochemical long-period grating fabrication in pure-fused-silica photonic crystal fiber

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We report on first photochemical recording of a long-period fiber grating (LPFG) in a pure fused silica photonic crystal fiber (PCF), which is based on two-photon absorption (TPA) of high-intensity femtosecond 264 nm pulses. The main disadvantage of previously used nonphotochemical methods of LPFG inscription in PCF fiber (electric arc, mechanical pressure or CO_2 laser irradiation) is that they easily damage the fragile holey structure, especially in PCFs with large hole diameters. Besides, photochemical LPFG fabrication in PCF not only allows recording by adding new periods to the grating, but also by repetitive exposure over the fixed number of periods. This important improvement results in production of stronger grating resonances with narrower bandwidths.

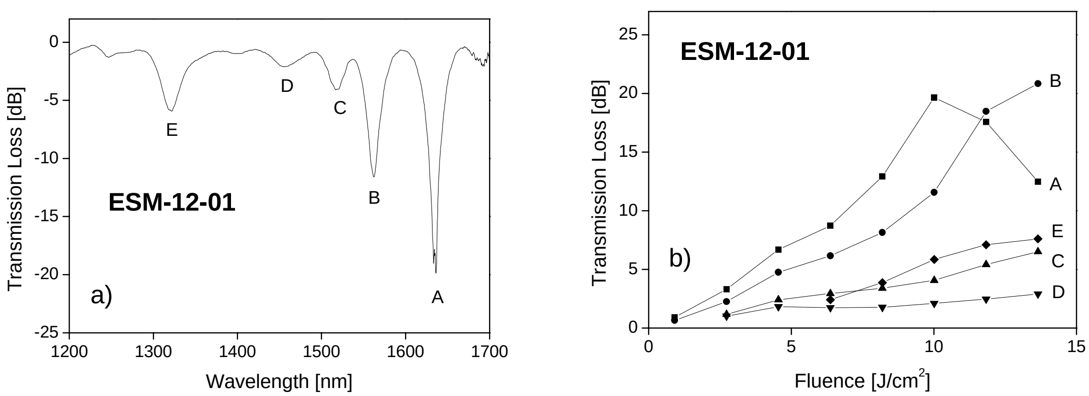

Fig. 1. (a) Transmission loss spectrum recorded with an irradiation intensity of 300 GW/cm^2 and total incident fluence of 10 J/cm^2; (b) transmission loss amplitudes for the peaks A, B, C, D, and E versus the total incident fluence.

In the experiments we used an endlessly single mode photonic crystal fiber ESM-12-01 and for comparison the standard telecom SMF-28 fiber. The pieces of the PCF, of 0.3–0.5 m long, were pigtailed to two 0.5 m long pieces of SMF-28 fiber by splicing. The hydrogenation of the ESM-12-01 and SMF-28 fibers was done under similar conditions. Both fibers were exposed point by point with a period of Λ = 500 μm. The length of the fabricated LPFGs was equal to 1 cm. For LPFG inscription, we applied femtosecond UV laser pulses (λ = 264 nm, $\varepsilon_p \approx$ 200 μJ, τ = 220 fs (FWHM), $2w$ = 0.3 cm (FWHM), f = 27 Hz).

The loss spectrum of the recorded LPFG (Fig. 1(a)) demonstrates an excellent LPFG quality (regular form of the peaks and absence of out-band losses) in spite of the two splices decreasing the initial signal level by 15 dB. From Fig. 1(b) it follows that at an incidence fluence of 10 J/cm^2 the peak A reaches its maximum (coupling factor is equal to $\pi/2$). Such an effect is common for LPFG inscription with a high value of excitation energy (i.e. using 157 nm light) and has never before been demonstrated in a PCF. But the most striking feature of the data presented in Fig. 1 (b) is the extremely low value of fluence necessary for the recording of an LPFG in a hydrogenated PCF. Indeed, for LPFG fabrication in a PCF, only 10 J/cm^2 fluence is enough to record a 20 dB peak (Figs. 1 (a), (b)). This value is much lower than the ~120 J/cm^2 fluence necessary for the inscription of ~24 dB transmission loss peak in SMF-28 (data not shown). In our opinion, the main reason for such an effect is the mechanical stress originating from the fiber drawing, which coincides spatially with the mode structure inside the inner cladding of PCF.

The temperature sensitivity of an LPFG recorded in a PCF is in the region −(250−490) pm/°C (for different transmission loss peaks, data not shown), which disagrees with the data for an LPFG recorded in the same PCF but using the electric arc approach (~0 pm/°C for the 1405 nm resonance peak).

References

1. G. Brambilla, A. A. Fotiadi, S. A. Slattery and D. N. Nikogosyan, “Two-photon photochemical long-period grating fabrication in pure-fused-silica photonic crystal fiber,” Opt. Lett. **31**, 2675−2677 (2006).