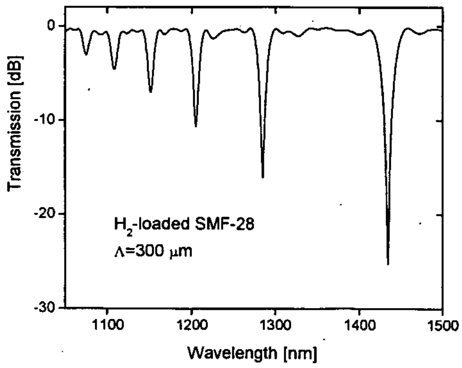
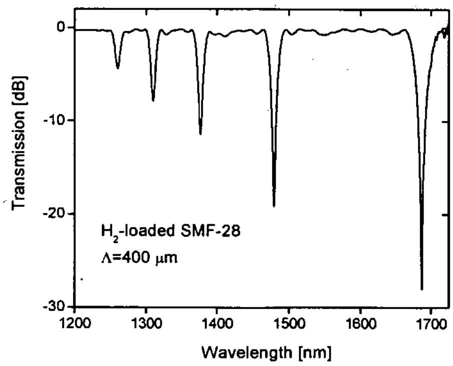
Inscription of long-period fibre gratings by high-intensity femtosecond radiation at 211 nm

A.I. Kalachev and D.N. Nikogosyan
Physics Department, University College Cork, Cork, Ireland

G. Brambilla
Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, UK

Long-period fibre gratings (LPFGs) have been investigated since the mid-1990s. The first LPFGs were fabricated photochemically by UV laser light at the wavelength coinciding with the maximum of the absorption band of defects in germanosilcate glass; that meant using either KrF excimer laser radiation (248 nm) or the second-harmonic radiation of a CW argon ion laser (244 nm). Such UV laser irradiation led to a refractive index change in the Ge-doped fibre core via a single-quantum photochemical reaction. Later, other methods of LPFG inscription, based on refractive index changes in the fibre core induced by thermal heating, were developed. Newly developed photochemical methods include the excitation of high-energy electronic levels in Ge-doped fused silica due to vacuum UV single-quantum and IR (visible) multiple-quantum techniques, respectively. Two years ago, we suggested the use of high-intensity 264 nm femtosecond pulses from a frequency-quadrupled Nd:glass laser for LPFG recording. In these experimental conditions, two-quantum excitation (two-photon or two-step, depending on the magnitude of linear absorption at the irradiation wavelength) takes place. Recently, we conducted a detailed investigation of LPFG fabrication by high-intensity femtosecond 264 nm light in both standard telecom and photosensitive fibres [1]. In this study we used the fifth harmonic of a femtosecond Nd:glass laser for LPFG fabrication in a hydrogenated SMF-28 fibre. In this case, the total excitation energy of two-quantum excitation reaches the value of about 11.7 eV, which is significantly higher than the bandgap energy value of 7.1 eV for Ge-doped fused silica.





In Fig.1 the transmission spectra, corresponding to the recorded LPFGs with the maximal value of transmission loss peak of about 25 dB for LP_{06} (grating period of 300 μm) and LP_{05} (grating period of 400 μm) cladding modes, are presented. The incident irradiation intensities and fluences were: 125 GW/cm^2 and 32 J/cm^2 (Λ = 300 μm); 110 GW/cm^2 and 21 J/cm^2 (Λ = 400 μm). In the case of low-intensity (~10 MW/cm^2) 193 nm inscription of 400-μm-period LPFG [2], a smaller value of transmission loss (20 dB) is reached at higher fluence of 80 J/cm^2. This corresponds to at least a 4 times difference in the inscription efficiency. In the case of high-intensity 264 nm recording of 300-μm-period LPFG [1], the similar value of transmission loss (24 dB) is reached at higher intensity (470 GW/cm^2) and similar fluence (38 J/cm^2). The estimates of the absorbed energy, using the newly measured value of the two-photon absorption coefficient for 3.5 mol.% Ge-doped silica (1.6 cm/GW), show that in the 211 nm case 12.1 % of the light energy entering the fibre core is absorbed by two-photon absorption and only 0.3 % by linear absorption, which testifies in favour of the two-photon mechanism of LPFG fabrication.

Reference

1. A.I. Kalachev, V. Pureur, D.N. Nikogosyan, "Investigation of long-period fibre gratings induced by high-intensity emtosecond UV laser pulses," Opt. Commun., in press.
2. B.-O. Guan, H.-Y. Tam, H.L.W. Chan, C.-L. Choy, M.S. Demokan, "Growth characteristics of long-period gratings in hydrogen-loaded fibre during and after 193 nm UV inscription," Meas. Sci. Technol., **12**, 818–823 (2001).