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Femtosecond laser direct-writing and poling of embedded grating structures

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In recent years, the use of a focused femtosecond laser to directly write structures deep within transparent media has attracted much attention due to its ability to write in three-dimensions [1]. By utilizing an amplified Ti:Sapphire laser (pulse duration 150fs, repetition rate 250kHZ, λ=850nm), we have developed a novel technique that enables us to write grating structures within the bulk of an optical fiber through its cleaved face, allowing control over light subsequently exiting the fiber. Fig 1(a) shows a microscope image of an embedded diffraction grating having a 5μm pitch and buried 25μm below a fiber's cleaved face. Fig 1(b) displays a far-field pattern created by a single-mode fiber which has a two-dimensional grating written 5μm below its cleaved face. The controllability of the power and direction of diffracting orders offers tantalizing opportunities for new methods of optical routing. A further grating of 20μm period and 4μm line width has been directly-written into a silica glass plate (Herasil 1). Thermal poling was carried out on the plate in air for 15 minutes at 280 °C with 4kV applied [2]. After poling the grating was investigated using a Nd:YAG laser (λ=1064nm), with a focused spot size of 20μm. The second harmonic was subsequently imaged by CCD camera. Fig 2(a) shows the second harmonic produced in a Gaussian beam away from the grating region as expected. However, Fig 2(b) shows the second harmonic produced at the position of the irradiated lines to be much stronger indicating that the $\chi^{(2)}$ is larger in the Ti:Sapphire irradiated regions. The incident beam is large enough to encompass two grating lines as indicated by the arrows. In Fig 2(a) the brightness is enhanced compared to Fig 2(b) to make the spot visible. By direct-writing periodic structures into silica fibers from the side and subsequent poling, work is currently underway to investigate the feasibility of achieving efficient quasi-phase-matching in silica fibres [3].

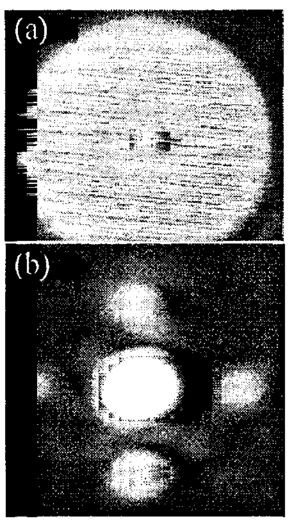

Fig.1. (a) A 5μm period diffraction grating written 25μm below a fiber's cleaved face. (b) Far-field pattern of single-mode light exiting a fiber containing an embedded 2-d grating.

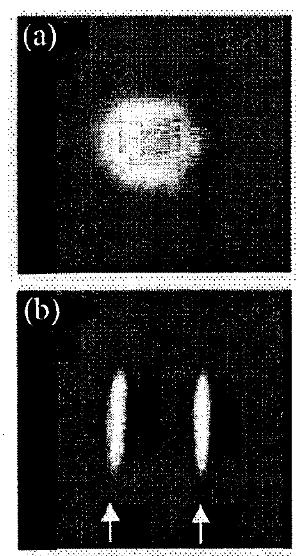

Fig.2. Imaging of the SHG. (a) Inclined incidence and well away from the grating. (b) Inclined incidence and on the grating.

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