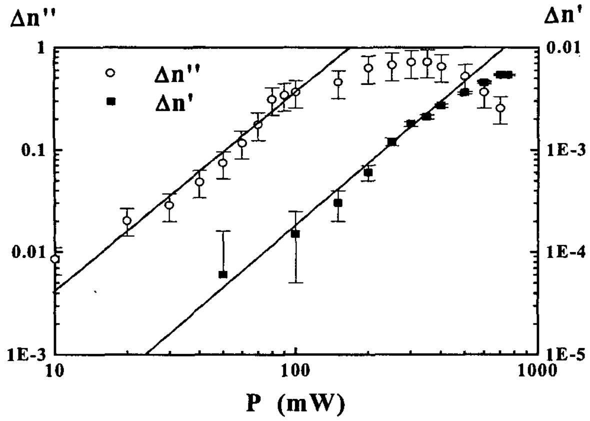
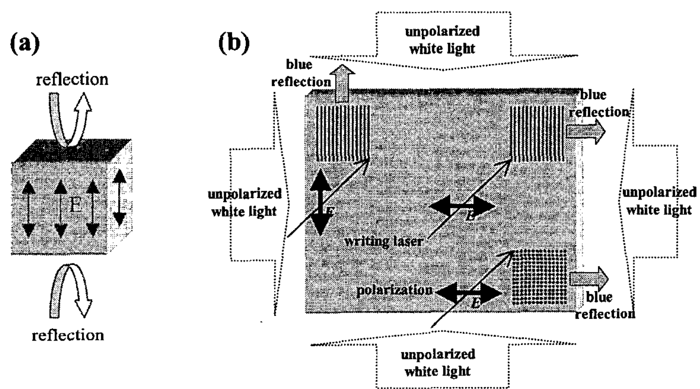
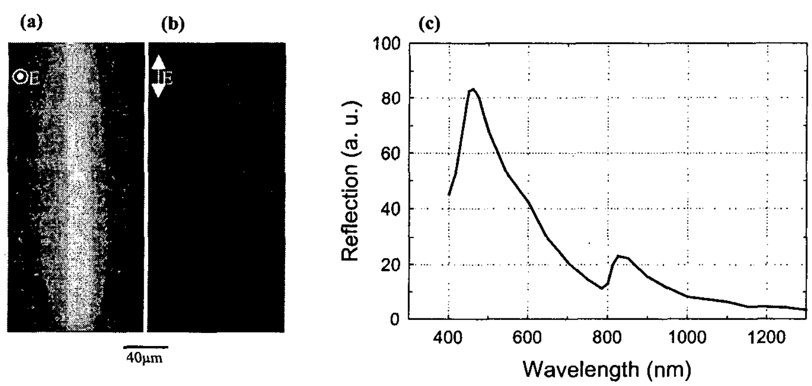


CMZ2 **Fig. 3.** Change of the real (Δn′) and imaginary part (Δn″) of the index of refraction in SF57 with respect to the pump energy. The lines are quadratic fits.



CMZ3 **Fig. 1.** (a) The polarization of the writing laser is recorded within the glass. Subsequent anisotropic reflection only occurs along its axis (b) Schematic of the direct-write geometry demonstrating the geometrical relationship between incident laser polarization and subsequent reflection.



CMZ3 **Fig. 2.** (a) A side-view of an embedded diffraction grating, demonstrating strong anisotropic reflection. The writing laser polarization is directed out of the page. (b) No reflection is seen from an identical structure created with orthogonally aligned polarization of the writing beam (c) Spectrum of the light reflected from the structure shown in (a).

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CMZ4 **4:30 pm**

Femtosecond Fabrication of Waveguides and Gratings in Chalcogenide Thin Films

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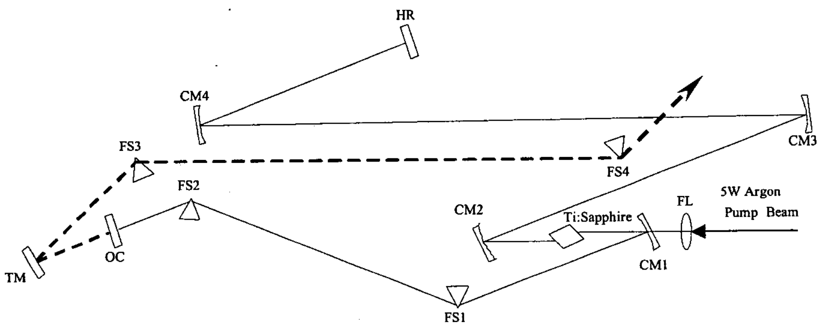
Optical waveguides can be fabricated through different techniques including photolithography, ion implantation and laser beam writing.[1] Structural modifications in materials can be obtained by focusing near-IR femtosecond laser pulses. Because the femtosecond regime minimizes the heat affected zone and the absorption is strongly nonlinear, cleaner, smaller and more repeatable structure feature sizes can be achieved.[2] Unamplified mode-locked Ti:Sapphire lasers have demonstrated the ability to micromachine optical materials.[3] A variety of optical devices fabricated with this technique have been reported for a variety of optical glasses.[4–6] Amorphous chalcogenide glass (ChG) films are candidates for all-optical integrated circuits for the telecommunication industry[6,7] due to their excellent infrared transparency, large nonlinear refractive index, and low phonon energies. This paper describes for the first time to our knowledge, material ablation and corresponding structural changes in single and multilayer ChG thin films, using an unamplified Ti:Sapphire laser.

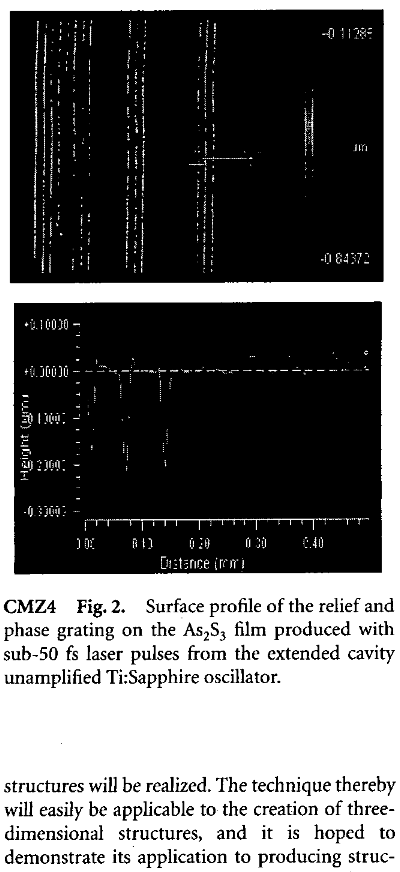
A special Ti:Sapphire laser was developed for these investigations. The purpose of this development was to generate pulses with energies in the 10's nJ range with sufficient intensity to reach thresholds for irreversible structural change at the optimal repetition-rate.[8] The cavity schematic is shown in Figure 1. The laser emission has a spectral bandwidth of approximately 40 nm (FWHM) centered at 800 nm and a repetition rate of 28 MHz. An interferometric autocorrelation measured sub-50 fs pulse duration. The system has an average output power of 0.55 W and produces energies up to 20 nJ per pulse. The output of the laser was focused by a 15×, 0.28 NA reflective objective onto a target attached to a 3D motorized translation system. The reflective objective minimizes the reflection loss and the normal dispersion induced by refractive microscope objective.

Using this experimental setup, relief and volume gratings with a 60 μm period were recorded on a 1.66 μm thick, As_2S_3 thin film by processing the sample in two exposure regimes. Firstly, the intensity was kept below the ablation threshold, generating a volume grating resulting from photoexpansion and an induced index change, as observed through an interferometric microscope. In the second regime, intensities *above* the ablation threshold produced a relief grating with grooves of 0.2 μm depth (Figure 2). Prior studies have linked bulk glass structural and optical property changes through Raman spectroscopy, showing that nonlinear absorption-induced index changes could be traced to local bonding changes in As_2S_3[9] (Figure 3).

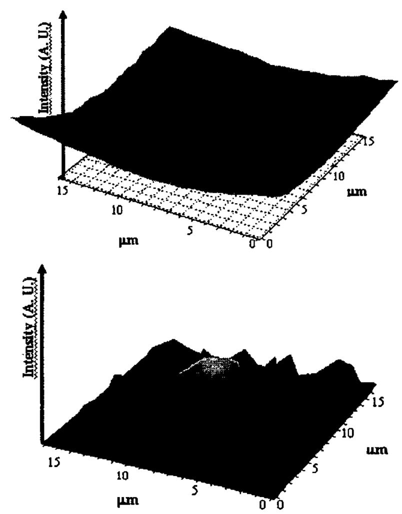
Thus, this approach to waveguide fabrication allows for the rapid production of volume microstructures as well as relief structures with the same laser without the need of costly and complex laser amplification systems. Combined with our ability to monitor glass structural changes with machining conditions, optimized, stable



CMZ4 Fig. 1. Extended cavity schematic of the unamplified Ti:Sapphire oscillator, where FL = 12.5 cm focal length lens; CM1, CM2 = 10 cm R.O.C. mirrors; HR = high reflector; FS1, FS2 = 60° fused silica prisms; TM = turning mirror; CM3, CM4 = 2 m R.O.C. mirrors; FS3, FS4 = fused silica prisms; OC = 12% output coupler.



CMZ4 Fig. 2. Surface profile of the relief and phase grating on the As_2S_3 film produced with sub-50 fs laser pulses from the extended cavity unamplified Ti:Sapphire oscillator.



CMZ4 Fig. 3. 2D Raman band map showing the spatial depletion of 345 cm^{-1} [As-S bonds] and emergence of the Raman bands centered at 236 cm^{-1} [As-As bonds] accompanying the writing of a 9 µm diameter waveguide with λ = 800 nm fs pulses in bulk As_2S_3.

structures will be realized. The technique thereby will easily be applicable to the creation of three-dimensional structures, and it is hoped to demonstrate its application to producing structures in multiple layers of photosensitive glasses. Improved focusing and irradiation conditions will lead to the fabrication of smaller features, opening the door for photonic bandgap structure fabrication.

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CMZ5 **4:45 pm**

The Effect of Temporal Pulse Shaping in Ultrafast Laser Ablation of Dielectrics

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Femtosecond laser ablation of dielectrics, especially of brittle materials, often results in specific collateral damage in the form of fracture and exfoliation, as a consequence of the mechanical stress induced in the material. Fast electronic relaxation in solids with strong electron-phonon coupling establishes a guideline for using temporally-shaped pulses[1] to exploit dynamical processes and optimize structuring with respect to the reduction of the residual damage.

First effects of a modulated excitation were extracted by studying laser-induced optical damage with temporally tailored pulses. Two extreme cases were considered; a-SiO_2 with ~100 fs electron trapping in self-induced deformations and Al_2O_3 where electrons remain quasi-free for tens of ps.[2]

Figure 1 (a) depicts the behavior of the damage threshold for single sequences of identical, double and triple pulses of different separation times, for Al_2O_3 and a-SiO_2, providing insights to the distinct trapping times. The results indicate a strong dependence of the multi-pulse optical damage threshold (MP-ODT) for a-SiO_2 on the separation time. The increase in the ablation threshold for a-SiO_2 is due to a loss in the electron population generated by the first pulse, affecting the subsequent ones. Constant behavior has been observed for Al_2O_3, where 100 ps electronic decay time is too long for the time scale involved.[2]

A similar dependence is observed in the multi-pulse damage dimensions (Fig. 1 (b)). A tendency towards smaller spot sizes is found for a-SiO_2 as the separation increases. Since damage will take place in the region where the electronic population exceeds critical density, the reduction in the affected area is due to the electronic decay at the wings of the Gaussian spatial irradiation during the dark time between the pulses. The decay implies less seeding electrons, collisional multiplication is inhibited, and damage will not occur in the low energy part of the spatial profile when the