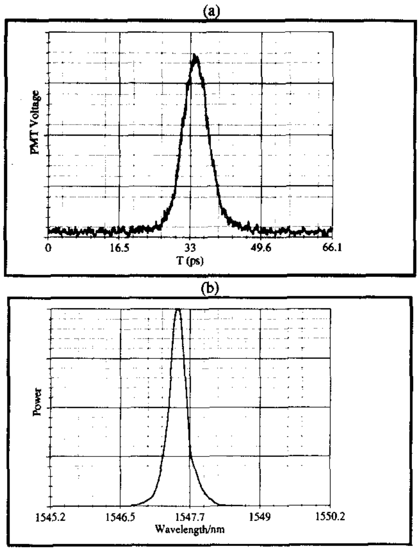

CFG3 Fig. 3. (a) Autocorrelation of the switched pulse at the second peak of the double-pass response. The autocorrelation indicates $sech^2$ pulses of 6.9 ps (FWHM), compared to launched pulses of 7.2 ps (FWHM). (b) Corresponding spectrum at second switching peak. The spectral width (FWHM) is 0.33 nm.

proximately N = 1 solitons into each arm of the NOLM. Moreover, the use of relatively long switching pulses reduces the effects of the soliton self-frequency shift in the arms of the NOLM, which, until now, has caused the device to fail at higher input powers.[2] Figure 2(b) shows the double-pass response, demonstrating enhancement of the single-pass response via steepening of the switching edges and improved input pulse power discrimination.

Figure 3(a) shows an autocorrelation of the pulse transmitted on the second peak together with its $sech^2$ fit, and Fig. 3(b) the associated pulse spectrum. Most notable is the extremely close resemblance in shape and duration of the transmitted pulse to the input pulse, showing a near perfect $sech^2$ intensity profile. In addition, the spectral characteristics of the pulse are maintained, indicating the robustness of solitons to NOLM cascades and the suitability of the emerging pulse to further optical processing.

We have demonstrated whole-pulse soliton switching in a cascasde of two NOLMs. A detailed spectral and temporal characterisation of both the single-pass and double-pass configurations will be given together with results from numerical simulations. Multiple-pass device responses and the effects of inter-loop loss and gain will also be presented.

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CFG4 **1145**

Soliton self-frequency shift for pulses with a duration less than the period of molecular oscillations

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Since the observation of the soliton self-frequency shift,[1,2] it has been known that the Raman effect has a profound impact on soliton propagation for solitons with durations less than a picosecond. According to the theory developed by Gordon,[2] under the condition that the soliton duration τ_p is much longer than the period of molecular oscillations $T_R = 2\pi\Omega_R^{-1}$ a soliton experiences a self-frequency shift, which is proportional to τ_p^{-4}. On the other hand, recently, in a number of experiments on soliton transmission and amplification in doped fibers,[3] solitons with durations as short as 20 fs were observed. Since the characteristic period of molecular oscillations in silica glass is about $T_r \simeq 80$ fs (corresponding to the Stokes frequency shift of $\Omega_R \simeq 440\ cm^{-1}$), in these experiments the condition $\tau_p < T_R$ is fulfilled. This implies a qualitatively new regime of stimulated Raman scattering (SRS) in which the spectrum of the initial pulse contains already both Stokes and anti-Stokes spectral components.[4] In this situation, the conditions for the validity of the theoretical model developed in Ref. 2 are not fulfilled, and an adequate analysis is required.

In order to investigate the effect of SRS on soliton evolution, we describe the SRS contribution to the polarization of a Kerr medium by a Raman-active two-level quantum oscillator. The effective Raman frequency Ω_R and the linewidth Γ_R of the oscillator is chosen so that the Raman response approximates the real one in silica glass. In the framework of the perturbation theory for soliton propagation we derive a general expression for the soliton self-frequency shift, which is valid as well for short pulses ($\tau_p < T_R$) as for long pulses ($\tau_p \gg T_R$).

We show that in the case of long soliton durations, $\tau_p \gg T_R$, the Raman response follows quasistationary the pulse intensity and may be expanded in a series with a small parameter. The first nonvanishing term of the expansion contributing to the self-frequency shift is proportional to the linewidth Γ_R and contains the time derivative of the soliton intensity. For the soliton frequency shift the dependence $(d\omega/dz) \sim \tau_p^{-4}$ is derived in agreement with the results of Ref. 2.

The attention is focused on the regime of SRS in which the pulse duration the condition $\tau_p < T_R$ is fulfilled. It is shown that contrary to the long-pulse-SRS in this case the Raman response has a "phase memory" and depends on the value of the pulse intensity at all the preceding moments of time. The self-frequency shift of the ultrashort soliton has been calculated to be inversely proportional to the soliton duration, $(d\omega/dz) \sim \tau_p^{-1}$. Since the process of SRS proceeds within the time interval shorter than both T_R and Γ_R^{-1}, the expression for the frequency shift does not contain the parameters T_R and Γ_R and depends only on the Raman polarizability of the medium. We emphasize that the investigated effect is directly related with the phenomenon of impulsive excitation of coherent optical phonons[5] and can play an important role in the transmission and amplification of femtosecond optical solitons.

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CFG5 **1200**

Efficient all-optical switching in a nonlinear AlGaAs X-junction

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Recently there has been a considerable amount of interest in all-optical switching using semiconductor waveguides operated at a wavelength corresponding to the half band gap.[1] In this spectral region there is an enhancement in the nonlinear refractive index coefficient, n_2, and the detrimental effects of two-photon absorption are minimised. By proper choice of material parameters, devices can be designed to operate in the 1.55 μm, low-loss window.

In this paper we report on switching results for a nonlinear X-junction. The nonlinear X-junction is of considerable interest because it has a digital switching response.[2,3] However, in order to observe efficient switching an optical phase change of the order of ~7π must be induced in the device. Previous results on nonlinear X-junctions showed a significant degradation due to three photon,[4] a process that becomes important at the high intensities required.[5] Here we report efficient all-optical switching, where the effects of three photon absorption have been minimised.

The X-junctions were fabricated in molecular-beam-epitaxy-grown layers of AlGaAs. The 1.5-μm-thick waveguiding films contained 18% Al, with upper and lower claddings of 24% Al, 1.5 μm and 4 μm thick respectively. X-junctions were formed using a combination of photolithography and dry etching with $SiCl_4$, to a depth of 1.3 μm. The resulting devices were 1.9 cm long and contained angles of 0.05°, 0.1°, 0.15°, and 0.2°.

The X-junctions were tested by endfire coupling the output from an additive-pulse mode-locked colour centre laser into one arm, using a 20X microscope objective. The two outputs were collected with a 60X objective and imaged onto two Ge photodetectors. The laser produced ~600 fs pulses at a wavelength of

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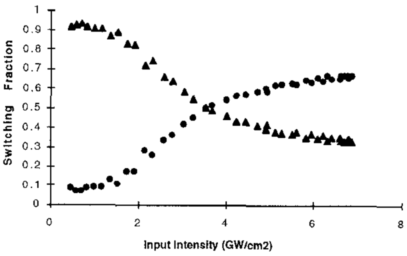

CFG5 Fig. 1. The normalised switching fraction, as a function of input intensity for a 1.9-cm long nonlinear X-junction.

1556 nm. Experimental results for the power dependent switching fraction of an X-junction are shown in Fig. 1. The input waveguides, which intersected at 0.05°, were symmetrical and 4 μm wide, the output waveguides were 3.9 μm and 4.1 μm wide. At low power the distribution of power at the output depends on the detailed interference between the fundamental and first-order modes in the junction region, in this case a split of ~15/85. As the input power is increased, more power propagates in the fundamental mode and exits from the wider, higher effective index, waveguide.

In conclusion we have observed all-optical switching in a 1.9-cm-long, nonlinear X-junction. The device was fabricated in AlGaAs and operated in the half band-gap spectral region.

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CFG6 1215

Transformation of linear chirp through cascaded optical second-order processes

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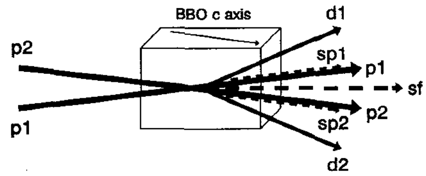
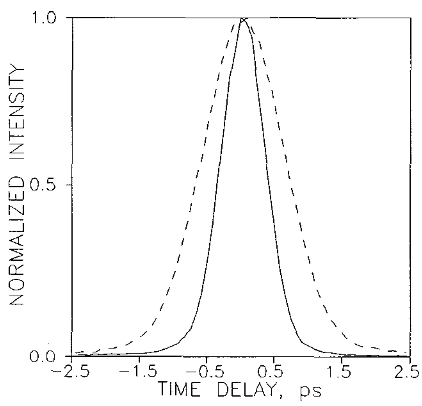
Ultrashort pulse self-modulation originating from cascaded second-order processes has been considered in a number of recent studies.[1,2] Two beam interaction resulting in self-diffraction has been shown to take place as well.[3,4]

We investigated a noncollinear degenerate sum-frequency generator, pumped by pulses with opposite signs of linear chirp. A simple description of the process could be given as follows (Fig. 1): besides the sum-frequency generation sf, simultaneously the second-harmonic generation (sp1 and sp2) of each pump beam (p1 and p2) occurs. The chirp steepness,



CFG6 Fig. 1. View of the experimental setup. Pump beams p1 and p2 are vertically polarized, while sum-frequency sf and second-harmonic sp1 and sp2 beams are polarized in the horizontal plane.



CFG6 Fig. 2. Autocorrelation traces, measured by a single-shot autocorrelator:compressed pump pulse (dashed line), compressed 1st diffracted pulse (solid).

considered as $\alpha = \partial\omega/\partial t$, experiences a two-fold increase in second-harmonic pulses: $\alpha_{sp1} = 2\alpha_{p1}$ and $\alpha_{sp2} = 2\alpha_{p2}$ (note that $\alpha_{p1} = -\alpha_{p2}$). The difference-frequency generation, expressed as $\omega_{d1,2} = \omega_{sp1,2} - \omega_{p2,1}$, results in diffracted pulses with chirps $\alpha_{d1} = 3\alpha_{p1}$ and $\alpha_{d2} = 3\alpha_{p2} = -3\alpha_{p1}$. For the second-order diffracted pulses one obtains $\alpha_{dd1} = 6\alpha_{p1}$ and $\alpha_{dd2} = -6\alpha_{p1}$. Finally this leads to enhanced compressibility of the diffracted pulses as compared with this of pump.

Experiments were carried out in a 7-mm BBO crystal (type I phase-matching, $\theta = 22.8°$). Two pump pulses of 5.9 ps duration p1 and p2 ($\alpha_{p1,2} = \pm 2.95\ cm^{-1}/ps$) of equal intensity were produced by fiberless CPA technique based Nd:glass system, employing an additional telescopic grating-pair compressor. In order to fulfill phase-matching conditions for all the cascaded interactions, the beams were intersected in the plane of noncritical phase matching.[3]

Compression data are depicted in Fig. 2. Dashed line represents compressed pump pulse before interaction. Assuming Gaussian shape, obtained duration equals to 1.02 ps with time-bandwidth product of 0.52. Diffracted pulse was compressed to 0.55 ps, preserving the same time-bandwidth product. Almost perfect diffracted pulse compression must be emphasized. Lower compression factor (~2; simple approach, given above points to 3) is determined mostly by pulse shortening in two-step nonlinear interactions. Nevertheless, chirp steepening occurs as expected; for diffracted pulse it was measured to be 8.32 cm^{-1}/ps. Self-diffraction efficiency exceeds 5%.

In conclusion, we have demonstrated chirp transfer and enhancement through cascaded second-order processes with high effective third-order nonlinearity. It is important to note that distortions due to self-modulation of the pulses were not observed close to perfect phase-matching conditions.

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CFG7 1230

Magnetic control of spatial soliton interactions

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There is currently quite a lot of interest in spatial solitons[1-3] planar optical waveguides. The first calculations, involving bright and dark solitons propagating in magneto-optic materials, will be reported. They follow up recent work of the authors, based on Lagrangian formalism. It will be shown that magneto-optic problems divide, roughly, into polar, longitudinal, and transverse configurations, according to the orientation of the magnetic field to the soliton propagation direction. The system consists of a thin nonlinear film, sandwiched between a linear, nonmagnetic, semi-infinite, cladding, and a semi-infinite, magnetic, linear substrate. It is assumed that the power levels are only sufficient to drive the film into a nonlinear state. The discussion will show that this is reasonable and that the longitudinal and polar cases are of maximum, strategic interest. Technically, both cases are controlled off-diagonal elements in the dielectric tensor, which are proportional to a parameter Q, which, when unscaled, lies between 10^{-2} and 10^{-4}. Although these values seem to be quite small, in absolute terms they compete vigorously with the nonlinearity. The starting point is a derivation of a new family of coupled envelope equations; all within the familiar, slowly varying amplitude, weakly nonlinear, weakly guiding formalism. We then demonstrate, by a scaling technique, that there exists an important, magneto-optic, cross-coupling term, which can sometimes be dominant. New parameters will be introduced that will be used mathematically, and numerically, to show that, with readily available materials, an external magnetic field is a powerful control parameter. The weakness of the nonlinearity is

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