Poling Techniques for Optical Fibres

L. Li and M. E. Fermann*

Introduction

Normally, only non-centro-symmetric crystalline materials exhibit second-order optical non-linearities. A material with a large second-order non-linearity is required for use in second-harmonic generation, Pockels modulators and parametric oscillators. Glass, being an amorphous material, exhibits the usual third-order non-linear behaviour, but not second-order effects. However, poling of an optical fibre by simultaneous excitation and orientation of defect centres has recently been demonstrated[1] and leads to the creation of permanent, large second-order non-linearities.

In this, defect excitation is accomplished via high-intensity blue light and their alignment via a strong externally applied electric dc-poling field (i.e. excitation poling). We show here that second-order nonlinearities ($\chi^{(2)}(2\omega = \omega + \omega)$ or $\chi^{(2)}(\omega = \omega + 0)$ may be induced by using either only blue light, or only a dc-field. Further, we investigate the dynamics, wavelength sensitivity, bleaching characteristics and limiting mechanisms of cw excitation poling. We measure a second- order nonlinear coefficient $\chi^{(2)}(2\omega = \omega + \omega)$ only 30 times less than for KDP and as a result of this work predict that by optimising poling parameters a further improvement by an order of magnitude should be possible.

Poling-field only

The application of only strong dc-fields (20V/μm–400V/μm) to optical fibres was found[2] to lead to the creation of the Pockels effect, $\chi^{(2)}(2\omega = \omega + 0)$, but unexpectedly no $\chi^{(2)}(2\omega = \omega + \omega)$. Additional excitation of the fibres by blue light had no effect on the magnitude of the induced $\chi^{(2)}(\omega = \omega + 0)$ (see Table 1).

rel. $\chi^{(2)}$	dopants	i	ii	iii
$\chi^{(2)}(\omega = \omega + 0)$ in 10^{-11} esu (Pockels eff.)	GeO_2–P_2O_5	0	8.6	8.6
	GeO_2	0	2.8	2.8
$\chi^{(2)}(2\omega = \omega + \omega)$ in 10^{-11} esu (SHG)	GeO_2–P_2O_5		10	0
	GeO_2	0.1		0

Table 1: Measured values of second-order nonlinear coefficients in silica-based oxide glass fibres. The results under (i) refer to "poling" by using only pulsed blue light; (ii) corresponds to cw excitation poling and (iii) corresponds to poling by using only a dc-field.

*Institut fur Allgemaine und Elektronik, Gußhausstraße 27–29, A–1040 Wien, Austria.

Defect excitation only

The launching of only high-intensity pulsed blue light (>200MW/cm^2) led to the creation of a very weak, spatially non-varying $\chi^{(2)}(2\omega = \omega+\omega)$. The wavelength sensitivity of the induced $\chi^{(2)}(2\omega = \omega + \omega)$ was established by exciting a range of germanosilicate fibre samples with different blue wavelengths and subsequently measuring the second-harmonic conversion efficiency with a YAG laser. Here modal phasematching between the fundamental and SH-mode was achieved by accurate control of the fibre design[3]. A strong resonance was observed at 480nm (see Figure 1), indicating that two-photon absorption via the 240nm absorption peak of oxygen deficient germanosilicate glass[4] lies at the root of the process.

Figure 1: Induced $\chi^{(2)}(2\omega = \omega + \omega)$ as a function of defect excitation wavelength in a germanosilicate fibre. A peak blue light intensity of 1.7GW/cm^2 was launched into a range of fibre samples for a period of 5 min each.

The highest magnitude of $\chi^{(2)}(2\omega = \omega + \omega)$ was created by cw-excitation poling using a cw-Argon laser operating at 488nm as the defect excitation source. An optimum cw blue light excitation intensity of about 400kW/cm^2 ($\approx$25mW power launched into the fibre) was found for a germanosilicate fibre. Higher blue light intensities had a negative effect on the SH conversion efficiency. The induced $\chi^{(2)}(2\omega = \omega + \omega)$ was permanent, but could be easily bleached by launching cw blue light only. cw-light of 514nm was found to be about 5 times less effective for the formation of $\chi^{(2)}(2\omega = \omega + \omega)$. The induced $\chi^{(2)}(2\omega = \omega + \omega)$ as a function of time and applied dc-electric field strength for a launched cw blue light power of 25mW at 488nm is shown in Figure 2. The induced $\chi^{(2)}(2\omega = \omega + \omega)$ is directly proportional to the applied field strength.

The induced $\chi^{(2)}(2\omega = \omega + 0)$ allowed the demonstration of a fibre Pockels modulator by using a modulating field of 1200 Volts. Optimisation of poling conditions in a P_2O_5-GeO_2-doped fibre should lead to values of $\chi^{(2)}(2\omega = \omega + \omega)$ approaching those of KDP and efficient second-harmonic generators.

Conclusion

We have shown that the value of the second-order nonlinearity which can be induced in optical fibres is strongly influenced by both irradiation by blue light and the existence of a strong poling field. Using the poling field alone resulted in a Pockels effect, but no second-harmonic generation, whereas for the latter, either blue light alone

Figure 2: Time and poling field-dependence of induced $\chi^{(2)}(2\omega = \omega + \omega)$ for a constant launched blue light power of 25mW at 488nm in germanosilicate fibre. The saturated induced $\chi^{(2)}(2\omega = \omega + \omega)$ is linearly proportional to the applied poling field strength and permanent. However, it may be bleached when blue light is launched in the absence of a poling field.

or (optimally) both blue light and a poling field together produced the largest non-linearity.

References

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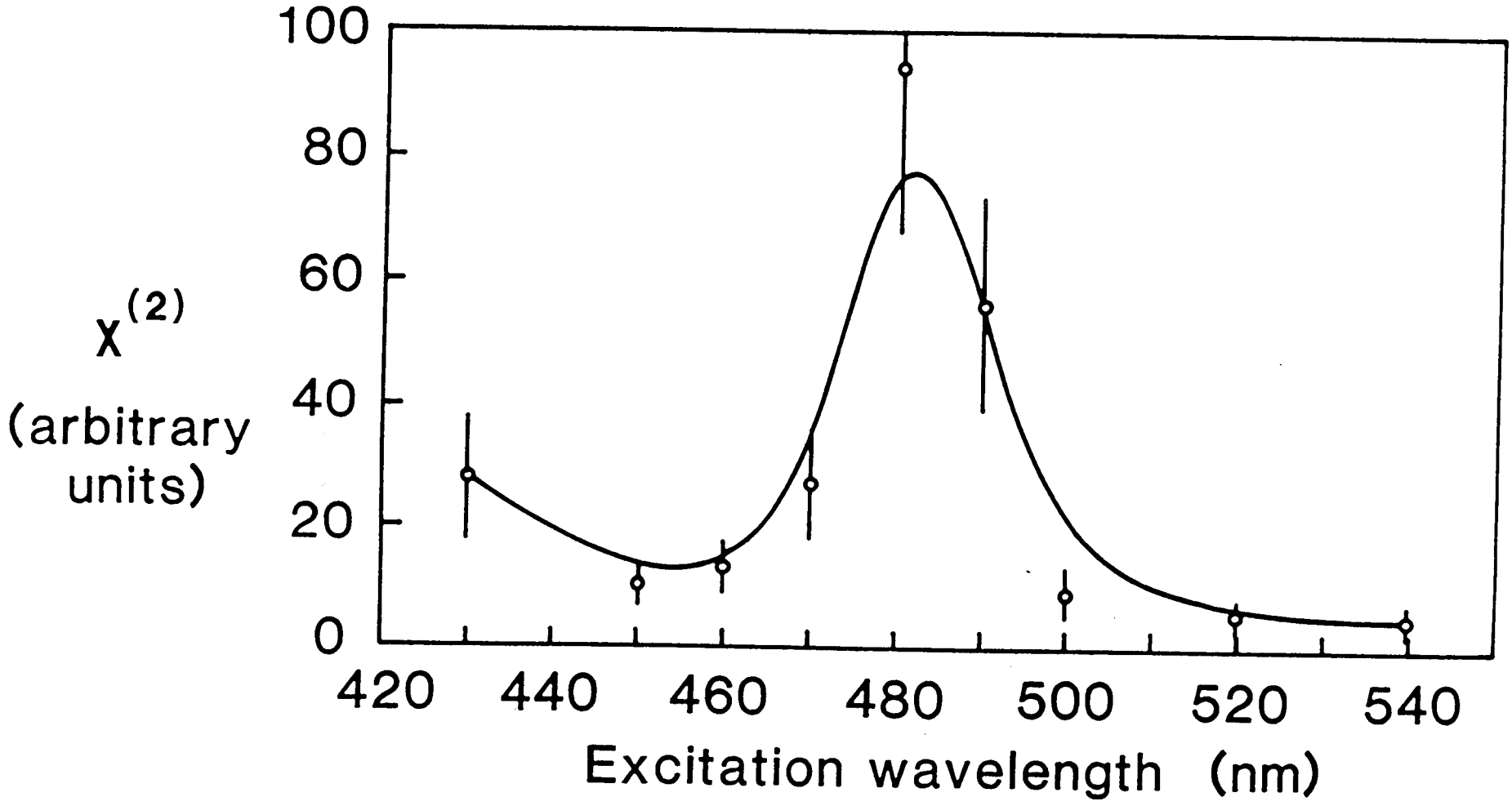

397 Fig·1

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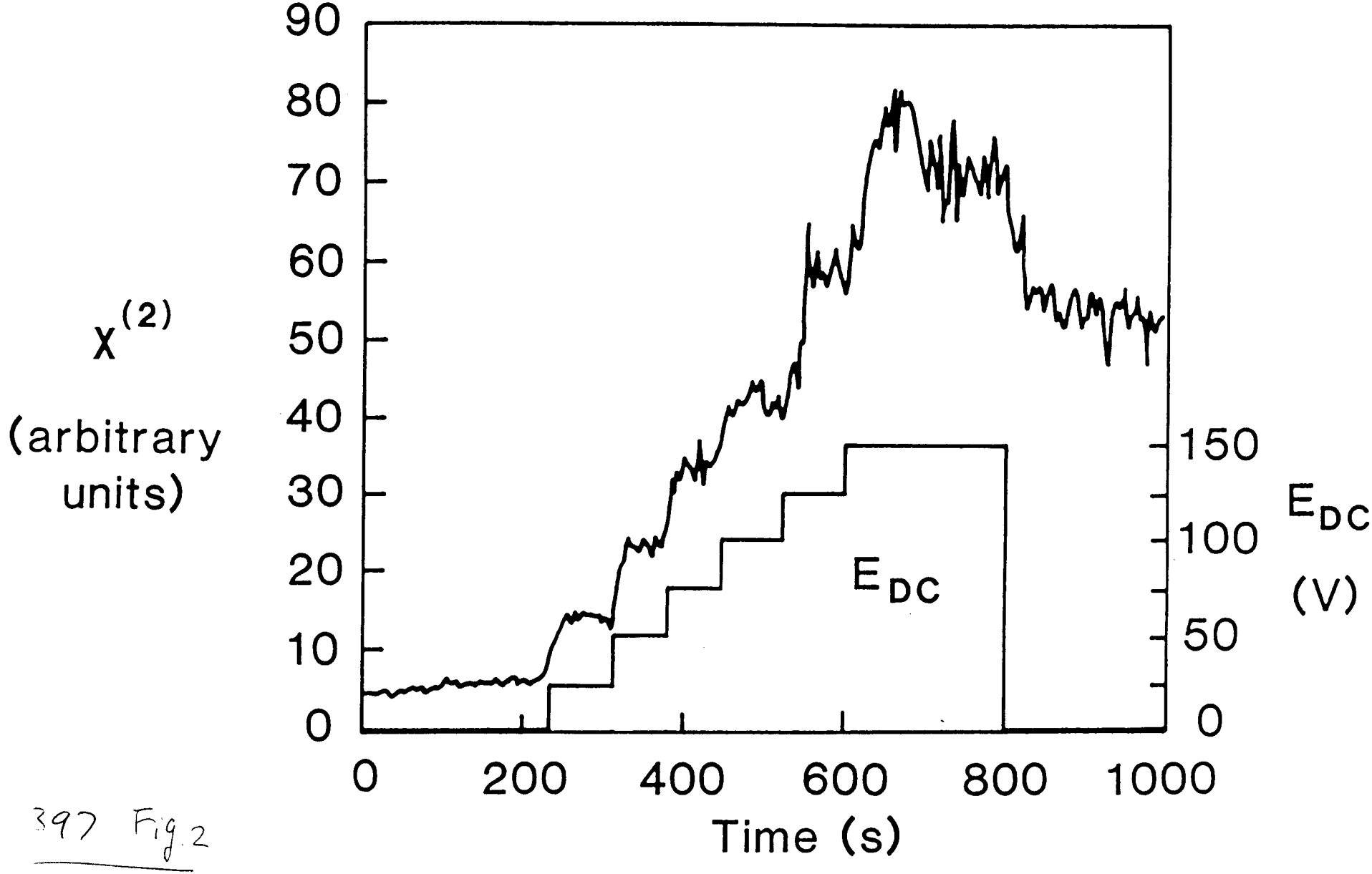

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