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# GLASS FIBRE POLING AND APPLICATIONS

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**Abstract**

Recent developments in the application of poled optical fibres to electrooptic light modulation and second harmonic generation are reviewed.

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Glass is a dominant material in fibre-optics technology. Recently, the discovery that dopants such as Ge and Ce render silica glass photosensitive has made possible the routine fabrication of important passive components such as fibre Bragg gratings. The absence of a second-order nonlinearity in glass however makes impossible the fabrication of active components such as modulators, switches, parametric frequency converters and frequency doublers. Thus, when efficient photoinduced second-harmonic generation was first discovered in fused silica fibres, wide-ranging studies ensued into the mechanism and properties of this unexpected phenomenon. Nonetheless, until fairly recently second harmonic generation in specially treated glasses and glass fibres has been of more scientific than practical interest, owing to levels of nonlinearity that were typically 3-4 orders of magnitude less than in the best nonlinear crystals[1-3].

During the past several years, however, second-order nonlinearities ~1 pm/V have been achieved in glasses using a variety of different techniques: thermal poling[4], corona poling[5] and electron implantation[6,7]. These observations have excited considerable interest because they offer the prospect of linear electro-optic modulators and frequency converters monolithically integrated into optical fibres or planar glass waveguides[8-15].

To date the thermal poling technique is the most promising. The nonlinearity is extremely stable and shows no degradation under illumination with intense visible and infrared light.

Electro-optic phase modulation has been demonstrated in a thermally poled fused silica channel waveguide made by electron implantation[16] and an electrooptic coefficient of about 0.3 pm/V has been measured in thermally poled silica glass[17]. Quasi-phase-matched frequency doubling of Q-switched Nd:YAG laser light at 1064 nm has been demonstrated in thermally poled silica glass[18]. The nonlinear coefficients, especially for electrooptic effect, are still small, and so require long interaction lengths. This is not a significant problem in fibre applications where the issues are cost, integrability and packaging, not length.

We now review recent developments in the application of poled optical fibre to electrooptic light modulation and second harmonic generation.

The first successful thermal poling of optical fibre was reported in 1994[19] and substantial improvements in the reproducibility and quality of the induced nonlinearity were obtained by vacuum poling[20]. The effective value of second order nonlinearity was about 0.2 pm/V.

The linear electrooptic effect has also been measured in poled silica fibres[21-23] and an electrooptic coefficient of 0.05 pm/V obtained.

Recently, periodically patterned second-order nonlinearities were created using thermal poling in vacuum and cw quasi-phase-matched frequency conversion to the blue in thermally poled silica fibres was demonstrated[24]. The bandwidth measured was 0.78 nm·cm, which is an order of magnitude larger than in an equal length of periodically poled bulk lithium niobate (0.06 nm·cm). Moreover, the group velocity mismatch at 860 nm is about 130 fs/mm in silica, compared to 1.8 ps/mm in lithium niobate. This may be of importance in short pulse work, where large acceptance bandwidths and long interaction lengths are desirable.

The effective nonlinear coefficients in poled fibres are still small. Considerable improvements are expected by optimizing the poling process, in particular by improving the overlap of the fibre modes and the poled layer and improving the fibre poling technology.

Last but not least, an electrooptic coefficient of about ~6 pm/V has been reported in germanosilicate fibre poled via internal electrodes[25]. Although UV excitation was used, it seems that this is not the major factor responsible for the high value measured. Indeed, even without UV excitation the measured coefficient is comparable to the one obtained in thermally poled fibres, and two to three orders of magnitude higher than in prior experiments made in fibres with internal electrodes[3]. The structure of the fibre used, in particular high Ge concentration, may be responsible. Further experiments are necessary to clarify the mechanism behind this exited result.

In conclusion, better understanding of the physical mechanisms behind glass poling[26-27] may lead to even higher values of nonlinearity and thence to the development of a range of new fibre devices.

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