Practical technique for measurements of second-order nonlinearities in thermally poled glasses

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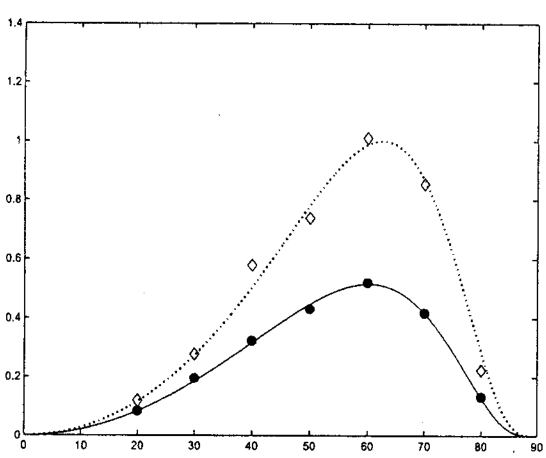
Poled glass is an attractive material for nonlinear optics applications. In particular devices such as wavelength converters and switches can be straightforwardly integrated in the present optical telecommunications. Several glass systems has been tested so far in order to find one in which is possible to induce high second-order nonlinearities, but discrepancies in the values of $\chi^{(2)}$ reported in point out that a reliable and practical technique is essential. Reliable $\chi^{(2)}$ measurements requires accuracy in the measurement of the thickness of the induced nonlinearity (L ~ 10 μm).

In this work we present a practical and non-destructive technique for measuring the thickness and the magnitude of $\chi^{(2)}$ in thermally poled glasses. Theoretical analysis shows that thicknesses, as small as 4 μm, can be measured with less than 10% error. The resolution is estimated in about 1 μm. The technique is tested on a set of poled silica sample and the poling dynamic as well as the $\chi^{(2)}$ evolution are derived.

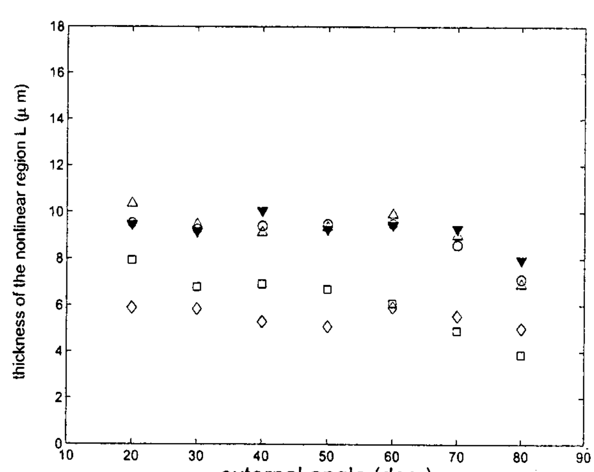
The nonlinear layer induced by thermal poling is close to the anodic surface of the glass. In our technique a stack is made by pressing in contact two identically poled glasses (alternatively the same one cut in two pieces) with the nonlinear surfaces facing each other. Like in the Maker's fringe technique (MFT) a laser beam is focused onto the stack and used as a pump to generate second harmonic (SH) light. The two nonlinear layers act as a source for SH light beams. Assuming a step profile for the nonlinearity, the SH beam intensity at the output, depends only on the relative phase between the two beams and therefore only on the thickness of the two layers. Measurements at different angles can be performed to improve the accuracy but they are not strictly necessary. It is possible to show that the SH efficiency ($\eta = P^{2\omega} / P^{\omega}$) for our "Stack" Maker's fringe technique (SMFT) is $\eta_{SMFT} = 4\,\eta_{MFT}\,(\sin(\pi/2\ L/l_c\ 1/\cos(\theta)))^2$ where θ is the SH internal propagation angle and l_c the coherence length (~24 μm in silica). Hence, L is obtained by inverting the previous equation. A single solution is found only when $L< l_c$. This is not a limit for the SMFT, it just states that the SMFT and MFT are complementary. It should also pointed out that the SMFT, as opposed to the MFT and other techniques, does not depend on the angular dependence of the Fresnel transmission losses and on the beam correction factors.

Thermal poling was carried out in air on a set of silica (Herasil 1) samples, 100 μm thick, at 280 °C, with 4kV applied for 7, 15, 30, 45, 90 minutes. SHG is performed with a modelocked and Q-switched Nd-YAG laser (λ=1064 nm) with a focused spot radius of w_o= 26 μm. A MFT and a SMFT measurements are performed (Fig. 1). From the ratio of the SH intensities at the different angles the nonlinear thickness is calculated (Fig.2). The experimental errors evaluated from the standard deviation are in general below 10%.

In conclusion we demonstrate a non-destrructive technique for the measure of the nonlinear thickness in poled glasses which together with high sensitivity and resolution join its simplicity of use. Moreover the use of this technique is not restricted to poled glasses but it is applicable to any nonlinear optical layer.



Normalized SH efficiency as a function of the fundamental external angle for MFT (solid symbols) and SMFT (open symbols). Data refers to the sample poled for 90 min.



Length of the nonlinear region in a set of silica plates poled for different times: (diamonds) 7 min, (square) 15, (up - triangle) 30, (down triangle) 45, (circles).