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Two-Beam Noncollinear Makers Fringe Technique

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A new technique to characterize second-order nonlinear films with sub-micron depth resolution is proposed. The potential of this method has been demonstrated in thermally-poled silica layers.

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It is now firmly established that during thermal poling of glass a thin depletion region is formed under the anodic interface and it is in this region that the induced second order nonlinearity ($\chi^{(2)}$) is concentrated. Many experiments also indicate that the $\chi^{(2)}$ is created via the intrinsic material $\chi^{(3)}$ and the frozen-in electric field. One of the most relevant quantities in understanding the poling process is the nonlinear depth (h) which is usually measured using the Makers Fringe Technique (MFT), extensively described in [1] and preferred to destructive chemical etching methods. However, as has already been pointed out [2], the MFT can only attain a rather limited internal angle (~40° in SiO_2) and therefore can distinguish between different film depths only if they are larger than a certain value (~15 μm @ 1.064 μm pump wavelength in SiO_2) which depends on the bound- and free-wave phase mismatch, Δk. A variation of the MFT has been proposed in [2] to overcome this limitation but it involves placing the sample between glass prisms and using index-matching fluid - a not always feasible alternative. We propose a two-noncollinear beam MFT that can measure nonlinear depths down to 2 μm with sub-μm resolution in glass and can be readily applied to second-order nonlinear films made of any other material. During the nonlinear interaction a second harmonic field ,

$$E(2\omega) \propto \int_0^{h(\alpha)} E_a(\omega)E_b(\omega)d_{eff}(z)e^{i\Delta k(\theta,\alpha)z}dz$$

is produced, where $E_a(\omega)$ and $E_b(\omega)$ are the two fundamental beams and $d_{eff}(z)$ is the nonlinear film profile. If h is varied continuously by rotating the sample then $E(2\omega)$ is an oscillating function of the rotation angle (α). The resolution is limited by Δk, which in turn depends only on the material, on the wavelengths involved and on the angle θ between the two fundamental beams. If $\theta = 0°$ then we return to the one-beam case described in [1] with the aforesaid problems. At large θ, Δk becomes much larger and resolution improves to sub-μm levels. In figure 1 we show experimental results for two samples poled for 5 minutes (in b) and for 30 minutes (in a) along with the theoretical curves which best fit the data. We were able to determine the nonlinear depths as 4.8 μm and 8 μm respectively. It is worth noting that the classical one-beam MFT gives two identical curves for such nonlinear-depth values and that our results are in excellent agreement with those obtained elsewhere with chemical etching.

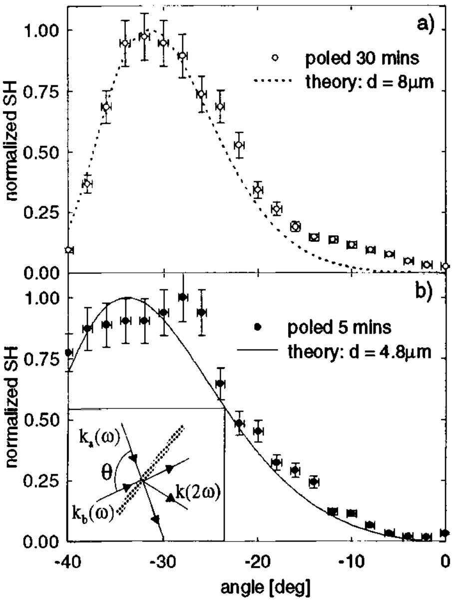

Fig. 1 Normalized SH as a function of the sample tilt angle (α) for a sample poled for 30 minutes (a) and 5 minutes (b), with relative theoretical curves. In the inset we show the experimental geometry.

[1] J. Jerphagnon and K. Kurtz. *J. Appl. Phys.* **41**(4):1667-1681 (1978)

[2] D. Pureur, A. C. Liu, M. J. F. Digonnet and G. S. Kino *Opt. Lett.* **23**(8):588-590 (1998)