(3) Ge(1) precursors offer three [and Ge(2) precursors, two] equally likely trapping positions for electrons; E_{pol} or $P_{dc}^{(3)}$ distorts the local structure surrounding the Ge(1) and Ge(2) precursors prior to capture, favoring one trapping position and hence causing color-center alignment. After capture, the bond angles change significantly, so a strong latch-on effect occurs, whereby a small perturbation in the initial condition results in a large permanent change in final alignment.

(4) These aligned $Ge^{+}(1)$ and $Ge^{+}(2)$ centers behave like nonlinear molecules, with intrinsic $\chi^{(2)}$ values. Although a strong correlation between Ge–Si bond breakage and $\chi^{(2)}$ has been found both by electron spin resonance and nonlinear spectroscopy, the alignment of the resulting GeE' centers is random and fixed in the glass matrix, so they are unlikely to contribute to a macroscopic $\chi^{(2)}$. This is explained by the fact that the broken Ge–Si bonds are merely electron donors and the $\chi^{(2)}$ level is proportional to the population of electrons donated.

In conclusion, color-center alignment offers a viable explanation for induced $\chi^{(2)}$'s in GS glasses; the talk will provide more evidence in support of this view.

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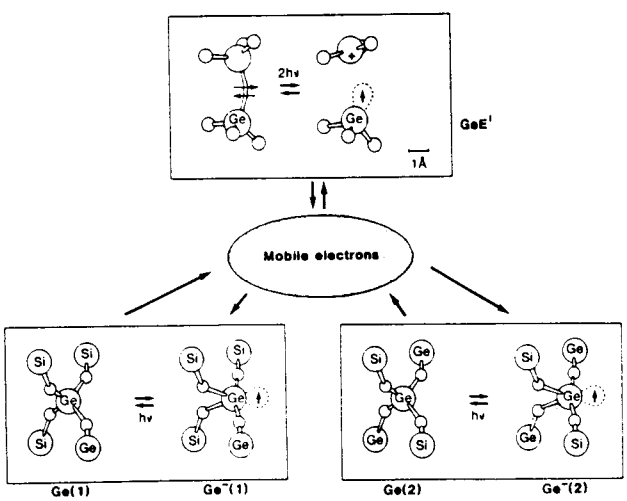

Fig. 1. Proposed color-center model. Electrons are passed among the Ge–Si bonds, GeE' centers, Ge(1) and Ge(2) precursors, and color centers. In the presence of a dc alignment bias [$P_{dc}^{(3)}$ or E_{pol}], preferential trapping occurs because of distortions in the electronic bond structure of the precursor molecules.

5:00 PM

MJ5 Generation of permanent second-order susceptibility in lead-silicate glass fibers

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The creation of a permanent second-order susceptibility [$\chi^{(2)}$] for second-harmonic generation (SHG) in Ge-doped silica fibers has been reported by several authors using various techniques (exposure to IR,[1] seeding with IR and its second harmonic,[2] dc-field poling with blue light,[3] and dc field only[4]). Although the microscopic mechanism governing this interesting phenomenon is still not fully understood, it has been suggested that the alignment of defect centers plays an essential role.[5] Defect centers, however, are known to exist or can be induced in many amorphous materials, including a variety of compound glasses that are commercially available. These commercially available compound glasses provide a wide range of options for the fiber core and cladding materials. Moreover, the effect observed to date in Ge-doped silica fibers may be present in a different and stronger form in fibers fabricated from compound glasses. It is therefore interesting to study fibers fabricated from various compound glasses. In this paper we report the first results, to our knowledge, for the dc-field poling effect in lead-silicate glass fibers.

The lead-silicate glass fibers used in the experiment contained 35 wt% PbO in the core (Schott F7) and had a numerical aperture of 0.44. They were D shaped, and the fiber had an internal electrode,[4] as shown in the inset of Fig. 1. A *Q*-switched Nd:YAG laser with 6-ns pulses and a 30-Hz repetition rate was used as the pump laser. The fibers were single moded at the operating wavelength of 1.06 μm.

An induced *permanent* $\chi^{(2)}$ was observed when the lead-silicate fibers were poled by using a dc electric field of 200 V/μm. However, it was observed only if the pump light and the poling field had been simultaneously present. Fig. 1A shows the variation of second-harmonic (SH) intensity with time. The pump power launched into the fiber was maintained constant, and the peak pulse pump power at the fiber output was typically 5 W (~0.05 GW/cm^2 in the core). The SH signal initially grew approximately exponentially when the field was on but decayed if it was removed and then saturated after undergoing poling for approximately 60 min. To check whether the pump light is an essential element in the poling process, the IR light was blocked and then unblocked (A and B in Fig. 1); the response indicates that the presence of the pump light is necessary for this poling process. The fiber was tested 16 h later after the field switched off, and it was found that the original SH signal had decayed to approximately one third. The final conversion efficiency was 0.02% for a pump peak power of only 5 W and for an electrode length of 5 cm. A conversion efficiency of more than 10% should be achievable when longer electrodes and a pump power of 100 W are used.

In conclusion, we have shown for the first time the existence of field-induced permanent $\chi^{(2)}$ in lead-silicate fibers. We believe that the studies of Ge-free compound glass fibers will reveal the fundamental causes of $\chi^{(2)}$ in optical fibers and may be of considerable practical importance if these fibers provide a route to a more efficient SHG process.

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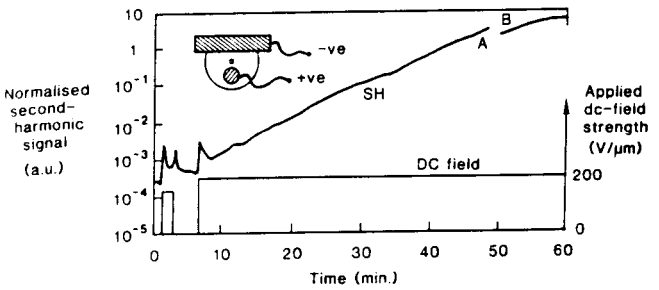

Fig. 1. Variation of second-harmonic intensity (normalized to pump intensity) with poling time. A and B indicate the time when the pump light was blocked and unblocked, respectively.

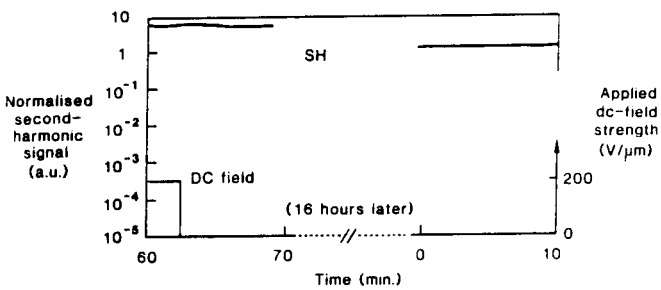

Fig. 2. (Time continuation of Fig. 1a.) SH signal after poling field switched off.

5:15 PM (Invited Paper)

MJ6 Second-harmonic generation in optical fibers: after four years of models, where are we?

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An understanding of this phenomenon is still at least a puzzle and possibly a fundamental problem in nonlinear optics. Various theoretical models are critically reviewed in light of the experimental evidence.