Submm. to CLEO
672

HIGH SECOND-ORDER NONLINEARITIES INDUCED IN GLASS BY ELECTRON IMPLANTATION

P.G. Kazansky, A. Kamal and P.St.J. Russell

Optoelectronics Research Centre,
University of Southampton,
Hampshire SO9 5NH,
United Kingdom
Tel. +44 703 593083
Fax. +44 703 593149

Abstract

A new technique for inducing a large permanent second-order susceptibility in glass is reported. The procedure involves implanting electrons by irradiating the glass with an electron beam. Second order nonlinearities $\chi^{(2)}$ as high as 0.7 pm/V are obtained.

HIGH SECOND-ORDER NONLINEARITIES INDUCED IN GLASS BY ELECTRON IMPLANTATION

P.G. Kazansky, A. Kamal and P.St.J. Russel

Optoelectronics Research Center,
University of Southampton,
Hampshire S09 5NH,
United Kindom
Tel. +44 703 593083
Fax. +44 703 593149

Any technique that permits the creation of a large second order nonlinearity in glass is of great practical and fundamental interest [1-4]. In this paper we report what is to our knowledge the first successful use of electron implantation to create a large permanent second-order susceptibility in glass.

Experiments have been carried out in samples of lead-silicate glass (Pb~45 wt%), silica glass and commercial soda-lime glass. A scanning electron microscope was used for electron beam irradiation of the samples. Areas of about 1 mm x 1 mm on the surface of the samples were irradiated in the electron microscope and tested using a Q-switched and mode-locked Nd:YAG laser operating at 1064 nm. No visible SH signal was observed in the treated samples of soda-lime glass. In contrast, relatively efficient SH generation (visible to the naked eye) was observed from the lead silica glass samples, which were exposed for about

1 min to the electron beam. The dependence of SH power on electron beam energy and current was explored. The SH efficiency was found to increase exponentially with the electron energy up to the limit of 40 keV imposed by the scanning electron microscope (Figure 1). It also increased with the electron beam current (Figure 2). For estimation of the thickness of the nonlinear layer the pump beam was focused on to the thin edge of the irradiated surface and the near-field pattern of the SH was imaged using a microscope objective and a video camera. The SH field distribution (Figure 3a) usually consisted of a central lobe of width 6 μm together with two weak side-lobes. By comparing the near and far-field patterns, the SH field in the side-lobes was found to be π out-of-phase with the SH field in the central lobe. In some regions of the glass samples the SH intensity of the side-lobes increased while the main lobe intensity decreased (Figure 3b and 3c). These results provide evidence for an electrostatic space charge field, caused by macroscopic charge separation that is concentrated near the electron-beam irradiated surface. The minima in the observed SH intensity distribution clearly coincide with the locations of space charge. The negative charge is concentrated at the electron implantation depth. The positive charge is located near the surface and is thought to arise through to secondary electron emission. Finally we obtained a value of second order susceptibility $\chi^{(2)} = 2\ d_{33} \sim 0.7$ pm/V, which yields an electrostatic field of magnitude $\chi^{(2)}/\chi^{(3)} \sim 2\times10^{6}$ V/cm, taking $\chi^{(3)} = 1.6\text{x}10^{-21}\ (\text{m/V})^2$. This value of nonlinear susceptibility is

about 40 times higher than the photoinduced one in this glass [5].

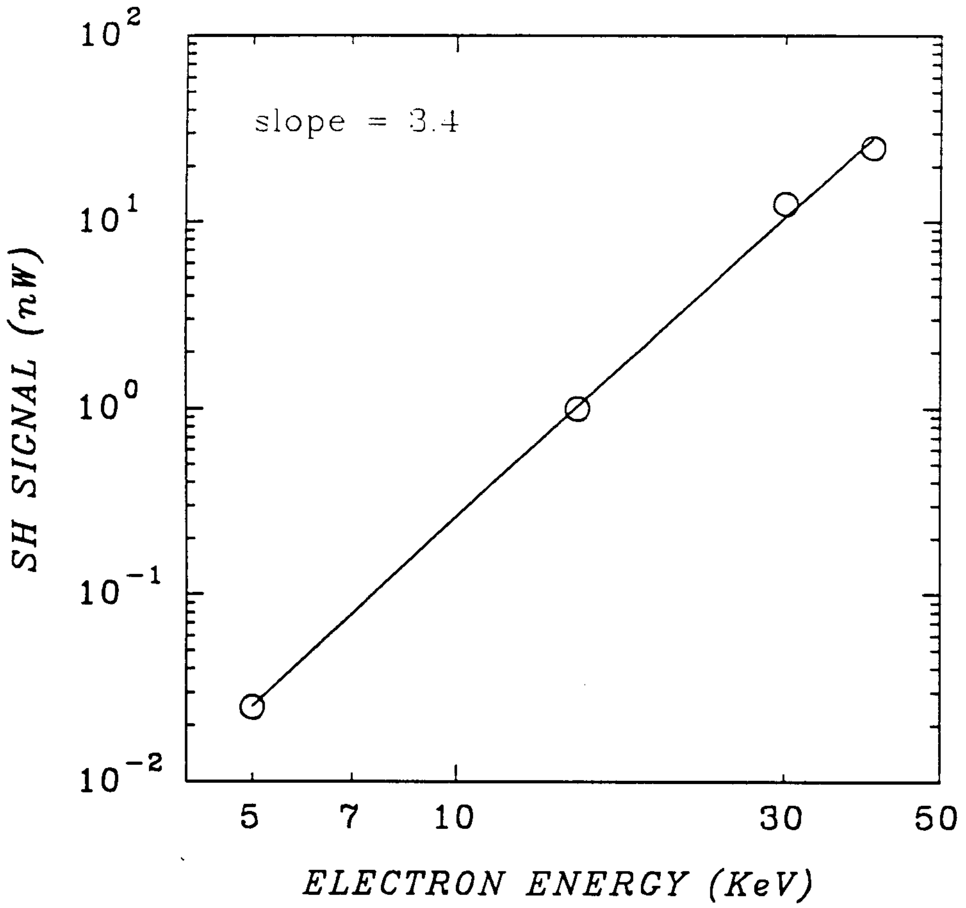
An extremely important practical advantage of the electron-beam technique is the ease with which quasi phase matching can be achieved - simply by programming the electron-beam machine to exposure the material in steps of the required period. A further important advantage of this technique is the possibility of inducing a $\chi^{(2)}$ in very pure glasses of low conductivity.

REFERENCES

1. U. Osterberg and W. Margulis, Opt.Lett. **11** 516 (1987).
2. M.-V. Bergot, M.C. Farries, L. Li, L.J. Poyntz-Wright, P.St.J. Russell and A. Smithson, Opt. Lett. **13** 592 (1988).
3. L. Li , P.J. Wells, E.R. Taylor, and D.N. Payne, in Digest of International Quantum Electronics Conference (Optical Society of America, Washington, D.C., 1990), paper QTh06.
4. R.A. Myers, N. Mukherjee, and S.R. Brueck, Opt. Lett. **16** 1732 (1991).
5. E.M. Dianov, P.G. Kazansky, D.S. Starodubov, and D.Yu. Stepanov, in Digest of Conference on Lasers and Electro-Optics (Optical Society of America, Washington, D.C., 1992), paper JTuA5.

FIGURE CAPTIONS

1. SH signal as a function of electron beam energy keeping the electron current fixed at 3 nA.
2. SH signal as a function of electron beam current, keeping the electron energy fixed at 40 keV.
3. Photographs of the SH near-field pattern in different regions of a lead-silicate glass sample.



slope = 3.4
SH SIGNAL (nW)
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
5
7
10
30
50
ELECTRON ENERGY (KeV)

FIGURE 1

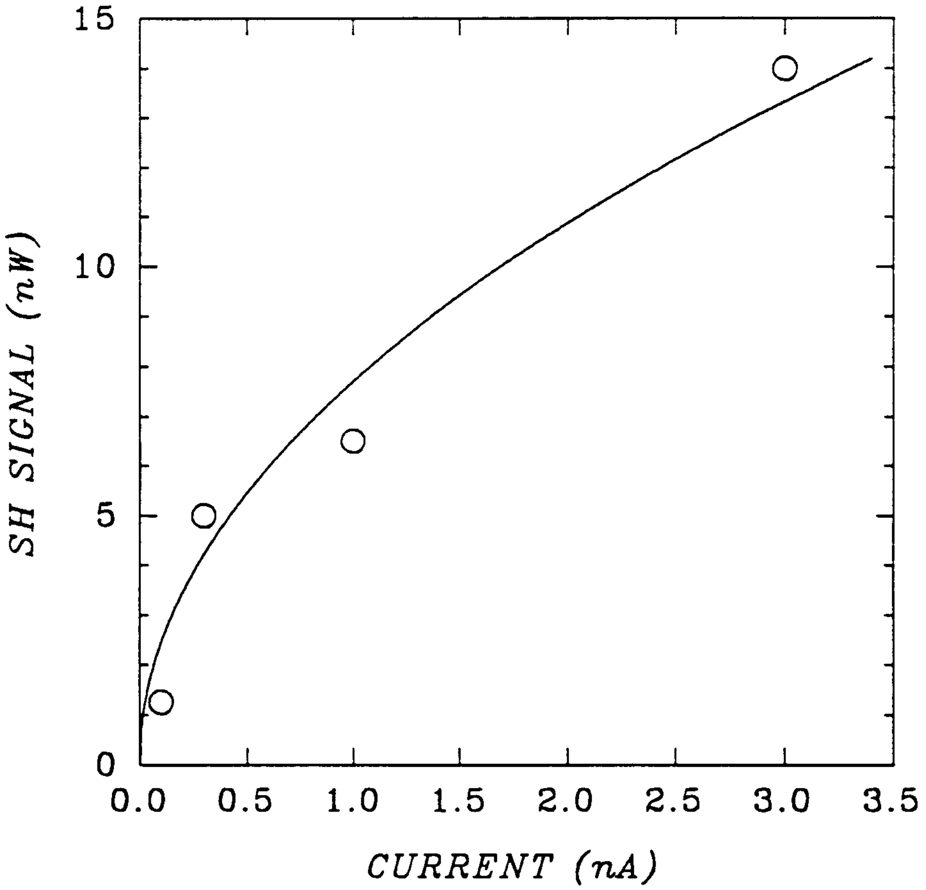


FIGURE 2

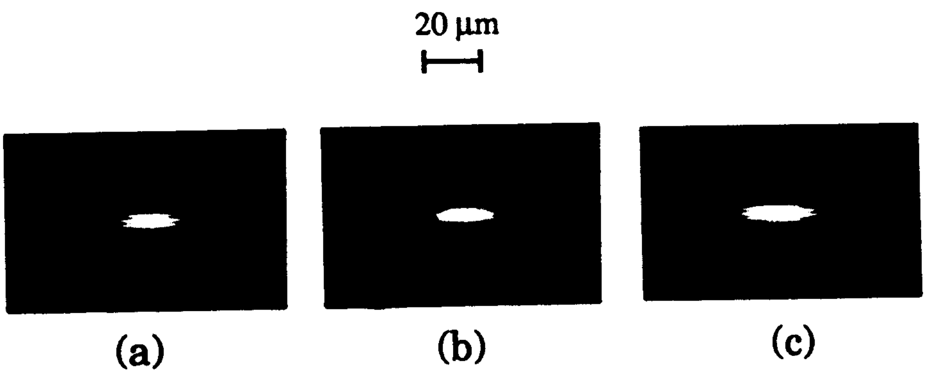


Fig. 3