

SHG in micron-scale layers of glasses: electron-beam irradiation vs thermal poling

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Supplementary material

Here we present details of electrostatic modeling, which we performed for analysis of internal electric field in electron irradiated samples. Subsequently, this field is used to estimate electric-field-induced second harmonic generation in the samples.

We consider electric field formed by an arbitrary distributed charge:

$$\operatorname{div}\mathbf{E} = \frac{1}{\varepsilon\varepsilon_0} \rho. \quad (\text{S1})$$

In the case of a glass sample irradiated with an electron beam, charge density ρ consists of bulk charges with density $-\rho_{bulk}$, implanted during the irradiation, and surface charges with density σ , located at the sample surface and compensating the bulk charge. Thus, expression for charge density is:

$$\rho(x) = \sigma \cdot \delta(x) - \rho_{bulk}. \quad (\text{S2})$$

Assuming that electric field outside the sample is zero, from Eq. (S1) in the 1D-case we obtain:

$$E(x) = \frac{1}{\varepsilon\varepsilon_0} \sigma - \frac{1}{\varepsilon\varepsilon_0} \int_0^x \rho_{bulk} dx. \quad (\text{S3})$$

Also, we assume that the bulk charge is completely compensated by the surface one, i.e.:

$$\sigma - \int_0^{+\infty} \rho_{bulk} dx = 0. \quad (\text{S4})$$

Substituting Eq. (S4) in Eq. (S3) we obtain:

$$E(x) = \frac{1}{\varepsilon\varepsilon_0} \int_x^{+\infty} \rho_{bulk} dx. \quad (\text{S5})$$

For intensity of generated second harmonic (SH) signal in a medium affected by strong electric field we can write [35]:

$$I_{2\omega} \sim \left| \int_0^{+\infty} E(x) \cdot e^{\frac{i\pi x}{L_c \cos \theta_i}} dx \right|^2. \quad (\text{S6})$$

In Eq. (S6) we implied that the second order susceptibility is defined by the third order one and by the electric field applied: $\chi^{(2)} \sim \chi^{(3)}\mathbf{E}$ [13]. In Eq.(S6) θ_i is angle of incidence of fundamental beam, $L_c = \frac{\pi\lambda}{2\Delta n}$ is a coherence length for the SH wave (λ – fundamental wavelength, Δn – difference

between refractive indices at fundamental and double frequencies). For the samples considered (Menzel and BF16) and for $\lambda \sim 1 \mu\text{m}$, the path of the laser beam is higher than the penetration depth of the charge (see Figure 5 in the main text). Thus, we assume the exponent in Eq. (S6) to be one, and Eq. (S6) is simplified to:

$$I_{2\omega} \sim \left| \int_0^{+\infty} E(x) dx \right|^2. \quad (\text{S7})$$

Using Eq. (S5) we calculated the electric field depth profile for given bulk charge distributions:

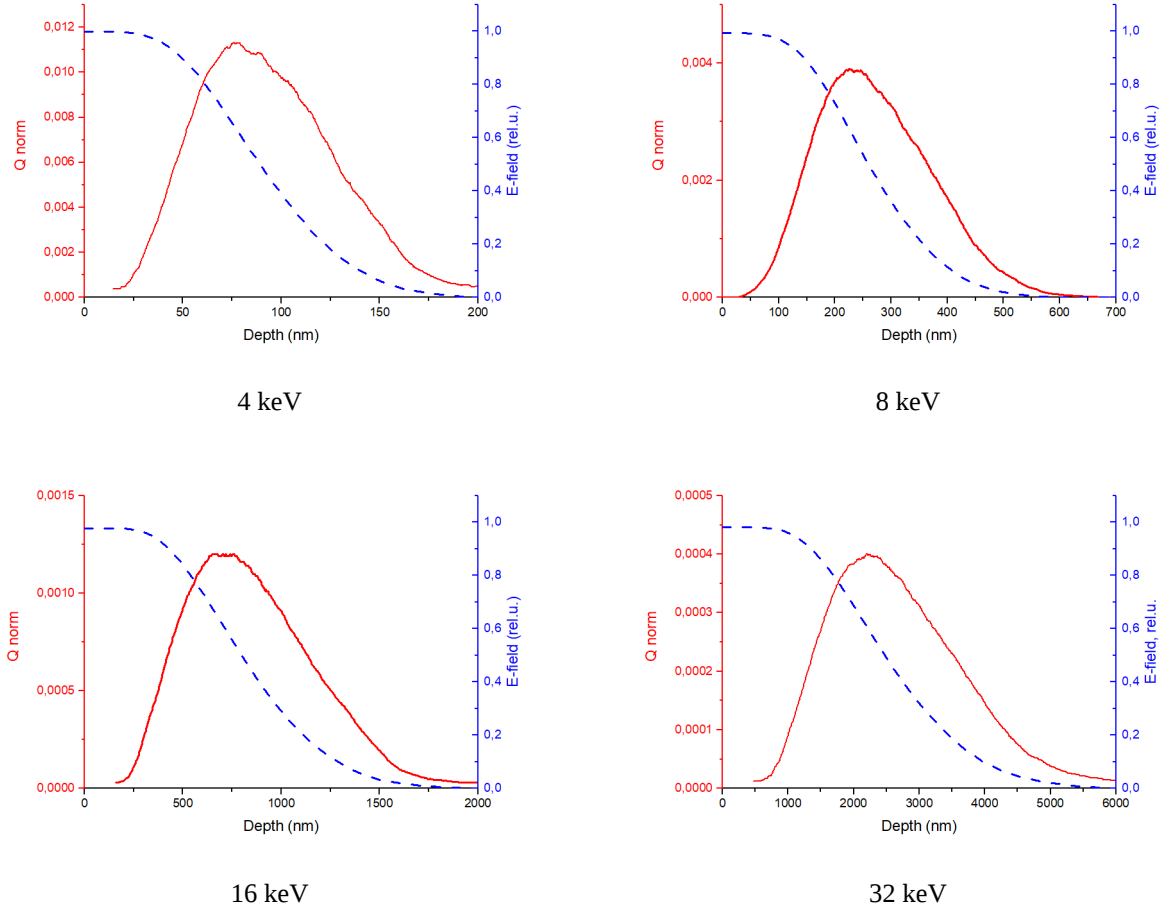


Figure S1. Normalized distribution of electric charge (solid, left axes) and the distribution of electric field (dashed, right axes) in e-beam poled BF16 glass irradiated with electrons of different energy. Electron energy is marked below corresponding graphs.

Note, that the electric field right under sample surface ($x = +0$) is unit (factor $\frac{1}{\epsilon\epsilon_0}$ is omitted) for all the cases because of the same injected charge in all the cases.