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Photo-induced pulsed crystal accelerator for generations of electrons, x-rays, and neutrons

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Photo-induced pulsed crystal accelerator for generation of electrons, x-rays, and neutrons

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ABSTRACT

Optical and electrical effects in semiconductors and ferroelectric crystals will be modeled. Standard photorefractive equations are supplemented by the equation of state for the polarization density following Devonshire-Ginsburg-Landau (DGL) approach. We have derived equations for pyroelectric and photogalvanic contribution to the holographic grating recording in ferroelectric materials. We will consider double-functional holographic interferometer, based on holographic pyroelectric current and optical beam coupling. Crystal electrostatic accelerators, based on charging of ferroelectric crystals by pyroelectric and photogalvanic effects are discussed in relation to generation of self-focused electron beam, X-rays and neutrons.

THEORETICAL MODEL

$$\nabla D = e(N - N_A - n)$$
$$J = dD/dt + e\mu nE + ed\nabla n + GsI(N_D - N)$$
$$dN/dt = sI(N_D - N) - rnN$$
$$\Gamma\, dP/dt + \alpha P + \beta P^3 = E$$
$$D = \varepsilon_0 \varepsilon_C E + P$$

Equation of state for spontaneous polarization, P, dielectric constant, ε_0, the concentration of: donors, N_D, ionized donors, N, acceptors, N_A, and electrons n, μ is the mobility of electrons, d is the diffusion coefficient, G is the photogalvanic vector coefficient, J is the total current, s is the absorption cross-section of photons, r is the recombination coefficient, and I is intensity of light. In the equation of state for spontaneous induction P, parameters Γ, $-\alpha$, $\beta > 0$ are kinetic coefficient's of the Devonshire-Ginsburg-Landau (DGL) theory of ferroelectrics

HOLOGRAPHIC GRATING RECORDING

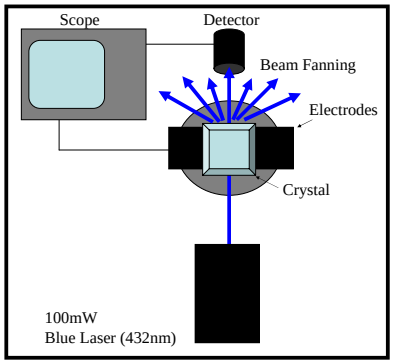
$$m = m_0 e^{i\varphi} \equiv \frac{2\sqrt{I_1 I_2}}{I_1 + I_2} e^{i\varphi}$$

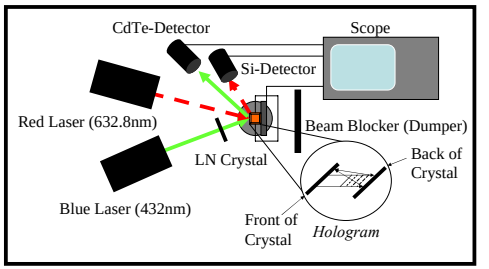
$$I = I_0[(1 + (\frac{m}{2} e^{i\vec{k}\vec{r}} + c.c.)] \equiv I_0 + (\Delta I\ e^{i\vec{k}\vec{r}} + c.c.)$$

STATE OF THE ART AND TECHNOLOGY TRANSFER

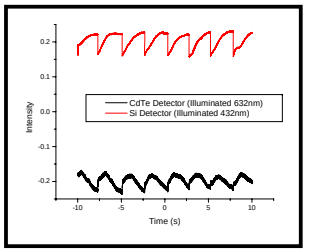
Potential applications include smart sensors, electrostatic actuators, and optical data storage.Optical excitation of the crystal can lead to many applications one of which is optical commuincation and optical data storage. The laser acts as a scanning source which runs across the crystal giving rise to the beam fanning. Interesting possibility for increasing efficiency of the crystal electrostatic accelerator is to use holographically recorded periodic electrostatic structures in the crystal surface for guiding and channeling of the electron beam. Space averaged components of the electric field (photoinduced and pyroelectric) may also charge the ferroelectric crystal surface to high voltage (exceeding 10 kV) and transform crystal in the compact electrostatic crystal accelerator, which can produce focused electron beam from the ionized surrounding air and generate X-rays and neutrons from the deuterated targets. This work is supported by the DoD and the Department of the US Navy. It is under the R1A research for CenSSIS.

EXPERIMENTAL SCHEMATIC





PRELIMINARY RESULTS AND ANALYSIS



The graph shows the optical excitation signals of LN detected by CdTe and Si-Detectors. The first curve is the detection of the optical signal from scattered light off the LN crystal to a Si-Detector. The second curve is the detection of the optical signal from scattered light off the LN crystal to a CdTe-Detector.

SUMMARY AND FUTURE STUDIES

We have developed a theoretical approach for the description of photo-induced and thermo-induced phenomena in ferroelectric semiconductors. In the description of dynamic holographic grating recording we included pyroelectric and photogalvanic contributions. Our preliminary results shows the optical pulses generated inside of LN can be detected by CdTe and Si-detectors. Running-grating schematic of the holographic recording can produce both optical effects (beam coupling) and electrical effects (holographic current). In the case of ferroelectric semiconductors pyroelectric component of the holographic current grows with the light intensity, that may be used for efficient power conversion from heat and light to electricity.

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