DF 14: Electric, electromechanical and optical properties II

Time: Thursday 14:00–17:20 Location: EB 407

DF 14.1 Thu 14:00 EB 407

Consequences of hopping charge transport for the relaxation of light-induced absorption in oxide crystals — •Christoph Merschjann, Bettina Schoke, and Mirco Imlau — Fachbereich Physik, Universität Osnabrück, D-49069 Osnabrück

Transient light-induced absorption changes $\alpha_{\mathrm{li}}(t)$ are observed in various nonlinear optical oxide crystals as, e.g., $LiNbO_3$, $KNbO_3$, $KTiOPO_4$, and β-BaB_2O_4. In contrast to basic assumptions the decay shape of $\alpha_{\mathrm{li}}(t)$ in these materials is generally not monoexponential. A fairly good — though empirical — description of the temporal evolution of the light-induced absorption is given by stretched exponential functions: $\alpha_{\mathrm{li}}(t) = \alpha_{\mathrm{li}}^{(0)} \cdot \exp\left[-(t/\tau)^{\beta}\right]$, with $0 < \beta \leq 1$. However, the origin of this peculiar behavior is still unclear. One possible reason may be a random-walk hopping transport of excited charge carriers, as predicted by the theory for small polarons in oxide crystals.

We present random-walk simulations of both band and hopping charge transport with different complexities. The results indicate that hopping transport is more likely to lead to the observed effects than classical band transport. The connection between transport models and mathematical descriptions of $\alpha_{\mathrm{li}}(t)$ is discussed.

Supported by the Deutsche Forschungsgemeinschaft (Projects IM 37/2-2, TFB 13-04, and GRK 695).

DF 14.2 Thu 14:20 EB 407

Absorption of ultra-short laser pulses in dielectrics — •Stefan Linden and Bärbel Rethfeld — TU Kaiserslautern

If an insulator is irradiated by a laser pulse of sufficient high intensity, non-linear ionization processes lead to an increasing free-electron density in the conduction band of the insulator. Free electrons enhance the absorptivity of the initially transparent material and are responsible for the optical breakdown of dielectrics. The transient free electron density is a fundamental parameter for numerous theoretical and experimental investigations and applications.

To describe the transient electron density in the dielectric several models exist. Commonly, a simple rate equation is applied to describe the evolution of the free-electron density under laser irradiation. Though this equation is proved for nano- to picosecond time scales, it fails on ultra-short processes. Here, the electrons energy distribution has to be taken into account, for example in the frame of the multiple rate equation [1].

In this study we present an extension of the multiple rate equation, taking into account the recombination of excited electrons from the conduction band to exciton states. Such exciton recombination was experimentally found to occur within about 200 fs for the case of SiO_2. We introduce the recombination time phenomenologically in the multiple rate equation and seek for an analytical asymptotic solution, giving information about the applicability of different approaches.

[1] B. Rethfeld, *Phys. Rev. Lett.* **92**, 187401, (2004).

DF 14.3 Thu 14:40 EB 407

Light-induced absorption in electrooptic PLZT ceramics — •Torsten Granzow[1], Silke Schaab[1], Dominik Schaniel[2], and Theo Woike[2] — [1]FB Material- und Geowissenschaften, TU Darmstadt, Germany — [2]Institut für Mineralogie, Universität zu Köln, Germany

Transparent polycrystalline materials such as lanthanum-modified lead-zirconate-titanate ceramics (PLZT) have electrical and electrooptical properties that can rival those of single crystals such as lithium niobate (LNB). At the same time, they offer all the advantages of ceramics, e.g. quick and cheap production in nearly arbitrary shape and size. However, there has been hardly any investigation of light-induced changes of the optical properties of PLZT such as its photorefractive behavior or light-induced changes of the optical absorption.

In this talk, we present measurements of the light-induced absorption in PLZT containing 8% La, 65% Zr and 35% Ti (PLZT 8/65/35). The samples are illuminated by a pulse from a Nd:YAG-laser, the resulting absorption change is detected by measuring the intensity of a probe laser behind the sample. A strong light induced absorption is detected in a broad spectral range. Its temporal development strongly depends on the probing wavelength: at high wavelengths there is a continuous decrease, lower wavelengths show an increase of the absorption for several microseconds before this absorption also finally subsides. This effect is attributed to the presence of two different electronic centers in the band gap. The results are discussed in comparison to LNB single crystals and with respect to possible photorefractive applications.

DF 14.4 Thu 15:00 EB 407

Space-charge waves of the low-frequency branch with a linear dispersion law — •Michaela Lemmer[1], Mirco Imlau[1], Manfred Wöhlecke[1], Mikhail P Petrov[2], and Konstantin Shcherbin[3] — [1]Department of Physics, University of Osnabrück, Osnabrück, Germany — [2]Ioffe Physico Technical Institute, St. Petersburg, Russia — [3]Institute of Physics, National Academy of Sciences, Kiev, Ukraine

ac and dc currents arising in CdTe:Ge during optical excitation of space-charge waves (SCW) have been investigated. The experiments have been performed at a wavelength of $\lambda = 1064$ nm using the technique of an oscillating interference pattern. Our investigations have shown that the SCW studied can be attributed unambiguously to trap recharging waves (TRW). Remarkably, we have found a linear dispersion law ($\Omega_K \sim K$) for these waves although an inverse law is usually expected. A corresponding theoretical model has been developed and shows that the theoretical data are in reasonable agreement with the experiments if the following fitting parameters are used: An effective trap concentration of $N_{\mathrm{eff}} = (2.5 \pm 0.3) \cdot 10^{12}$ cm^{-3}, a mobility-lifetime product of $\mu\tau = (0.65 \pm 0.05) \cdot 10^{-7}$ cm^2/V, and a Maxwell relaxation time of $\tau_M = (5.5 \pm 0.2) \cdot 10^{-3}$ s. The appearance of an additional low-frequency ac resonance is discussed in the frame of a bipolar conductivity.

Financial support of the Deutsche Forschungsgemeinschaft (DFG, projects GRK 695 and RUS 17/15/07) is gratefully acknowledged.

DF 14.5 Thu 15:20 EB 407

Untersuchung des photorefraktiven Effekts in Lithiumniobat-Kristallen mit Femtosekunden-Laserpulsen* — •Dominik Maxein, Stephan Kratz, Daniel Haertle und Karsten Buse — Physikalisches Institut, Universität Bonn, Wegelerstr. 8, 53115 Bonn

Der sogenannte photorefraktive (PR) Effekt spielt bei vielen Anwendungen von Lithiumniobat-Kristallen ($LiNbO_3$) eine wichtige Rolle: Einerseits kommt es durch Brechungsindexänderungen bei hohen Intensitäten zum „optischen Schaden“, durch den das Strahlprofil zerstört wird. Andererseits bietet er die Möglichkeit, Brechungsindexstrukturen und diffraktive optische Elemente in $LiNbO_3$ einzuschreiben, aber bisher im Wesentlichen nur mit sichtbarem Licht.

Kürzlich wurde mit Einstrahlexperimenten gezeigt, dass der PR Effekt in $LiNbO_3$:Fe auch bei Licht der Telekommunikationswellenlänge 1,5 μm auftritt, wenn man fs-Pulse verwendet [1]. Allerdings zeigt er dort Besonderheiten: Man erreicht vergleichsweise hohe Brechungsindexänderungen Δn und beobachtet einen Vorzeichenwechsel des Δn-Musters beim Wechsel der Schreiblicht-Polarisation. Um den PR Effekt sowie diese Besonderheiten besser zu verstehen, wird das Schreiben und Löschen von Gittern in $LiNbO_3$ mit fs-Laserpulsen untersucht und mit cw-Messungen verglichen. Dabei kommt sichtbares (532 nm) und infrarotes Licht (776 nm) zum Einsatz.

* Gefördert von der DFG und der Deutschen Telekom AG.

[1] O. Beyer et al.: "Photorefractive effect in iron-doped lithium niobate crystals induced by femtosecond pulses of 1.5 μm wavelength," Appl. Phys. Lett. 88, 051120 (2006)

DF 14.6 Thu 15:40 EB 407

Polungsverhalten und Brechungsindex in magnesiumdotiertem Lithiumniobat nach Bestrahlung mit hochenergetischen Ionen — •Lena Jentjens[1], Hilke Hattermann[1], Konrad Peithmann[1], Matz Haaks[1], Karl Maier[1] und Michael Kösters[2] — [1]Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn — [2]Physikalisches Institut, Universität Bonn

Mit Magnesium dotiertes Lithiumniobat ($LiNbO_3 : Mg$) ist auf Grund des stark unterdrückten photorefraktiven Effekts für viele Anwendungen interessant. Durch die Bestrahlung mit leichten, hochenergetischen Ionen wie ^{3}He mit einer Energie von 41 MeV werden wichtige Materialeigenschaften geändert. In der bestrahlten Region, in der die Ionen den Großteil ihrer Energie noch nicht abgegeben haben (vor dem Bragg-Peak), ist das ferroelektrische Koerzitivfeld E_C um 0.6 bis 1.0 kVmm^{-1} vermindert. Das Umpolen von Domänen in bestrahl-

ten Bereichen wird so im Vergleich zu unbestrahlten Bereichen entscheidend erleichtert. Außerdem werden im Kristall thermisch stabile Brechungsindexänderungen in der Größenordnung 6×10^{-3} durch die Bestrahlung verursacht. Diese Eigenschaften sind besonders im Bereich der kleinräumigen Strukturierung interessant, die unter anderem bei Anwendungen in der nicht-linearen Optik eine große Rolle spielt. (*gefördert durch DFG-FOR 557)

DF 14.7 Thu 16:00 EB 407

UV-assisted electrical field poling of magnesium-doped lithium niobate crystals* — •Hendrik Steigerwald, Fabian Luedtke, and Karsten Buse — Institute of Physics, University of Bonn, Wegelerstraße 8, 53115 Bonn, Germany

Periodically-poled lithium niobate ($LiNbO_3$) with domain structures in the micrometer regime is intensively investigated due to its increasing importance, e.g. for nonlinear optics using quasi phase matching. Efficient second harmonic generation in this material is usually hampered by optical damage, i.e. undesired index and absorption changes. Mg-doping increases the optical damage threshold, however complicates the poling process especially for small domain structures. We obtain such domain patterns in Mg:$LiNbO_3$ crystals by a combined approach using electric field poling and a superimposed UV light grating. Illumination with UV light decreases the coercive field of Mg:$LiNbO_3$ and enables smooth domain wall propagation. Structured coating of a z-cut Mg:$LiNbO_3$ crystal with UV-absorbing photoresist that has high electrical resistance enables electrical pulse poling of domain structures. The resulting domain patterns are investigated for different types of crystals and different poling parameters. Using this approach we also fabricated surface domains in proton exchanged α-phase waveguides.
*Financial support of the DFG and the Deutsche Telekom AG is gratefully acknowledged.

DF 14.8 Thu 16:20 EB 407

Self-induced fixing of index gratings in $LiNbO_3$:Fe using a single laser beam — •Volker Dieckmann, Andreas Selinger, and Mirco Imlau — Department of Physics, University of Osnabrück, Barbarastr. 7, D-49069 Osnabrück, Germany

Self-induced fixing of noisy refractive-index gratings is discovered in single crystals of iron-doped $LiNbO_3$ (0.1 wt.% Fe) upon long-term exposure to a single laser beam of high intensity ($I = 100$ W/cm^2) at ambient temperature. The extraordinary polarized laser beam ($\lambda = 532$ nm) impinges normal to the c-axis of the sample. At the beginning of exposure, this results in the recording of noisy refractive-index gratings and in a nearly symmetric angular intensity distribution in $\pm c$-direction of scattered light (Goulkov et al., Phys. Rev. B, 65, 195111 (2002)). Further exposure to the high intense laser beam leads to a decrease of the scattered light intensity and, on the long-term, to an increase of an asymmetric scattering intensity distribution in $-c$-direction only. This distribution cannot be erased by white-light exposure, i.e. the underlying noisy refractive-index gratings are permanently fixed. Temperature-dependent measurements of the thermally activated decay of the gratings yield an activation energy of (0.97 ± 0.06) eV, which points to a contribution of charge-carriers with a low mobility, such as ions. The experimental procedure and the measured activation energy suggest an explaination via the effect of laser-induced local heating of the sample in combination with the well-known simultaneous thermal fixing procedure.

Financial support by the DFG (projects IM 37/2-2, GRK 695).

DF 14.9 Thu 16:40 EB 407

Optical cleaning of lithium niobate crystals for reduction of optical damage* — •Michael Kösters[1], Patrick Werheit[1], Daniel Haertle[1], Karsten Buse[1], and Boris Sturman[2] — [1]Institute of Physics, University of Bonn, Wegelerstr. 8, 53115 Bonn, Germany — [2]Institute of Automation and Electrometry, 630090 Novosibirsk, Russia

A method for the reduction of optical damage in lithium niobate crystals is presented: The crystals are illuminated with a focused laser beam giving rise to strong bulk photovoltaic electronic currents. At the same time, application of high temperatures of about 180 °C prevents the build-up of space charge fields by enhancing the mobility of ionic compensation charges, such as hydrogen ions. Experimentally, the method is similar to "thermal fixing" used for persistent hologram recording. Optimum choice of the light pattern plus heat however dramatically decreases the concentration of photoexcitable electrons in the exposed region leading to a suppression of optical damage. Experiments with slightly iron-doped crystals have shown an increase of the threshold for optical damage of more than 100 compared to untreated crystals. Crystals treated with this method could be of great use for non-linear optics, especially for applications using periodically-poled structures to enable quasi-phase matching: in contrast to magnesium doping for optical damage reduction, the method does not affect the good poling characteristics of undoped lithium niobate.

*Financial support from the Deutsche Telekom AG is gratefully acknowledged.

DF 14.10 Thu 17:00 EB 407

A model for the thermo-electric oxidization of lithium niobate crystals* — •Stephan Gronenborn[1], Boris Sturman[2], Matthias Falk[1], Daniel Haertle[1], and Karsten Buse[1] — [1]Institute of Physics, University of Bonn, Wegelerstr. 8, 53115 Bonn, Germany — [2]Institute of Automation and Electrometry, Novosibirsk 630090, Russia

Lithium niobate is an important material for many applications in optics e.g. electro-optic modulators, holography and frequency conversion. Using $LiNbO_3$:Fe, concentrations of Fe^{2+} and Fe^{3+} ions are important factors determining the performance of the material. Recently, a method to strongly oxidize highly doped crystals (0.5 - 3 wt.% iron in the melt), the thermo-electric oxidization treatment, was reported [1]. The crystals are annealed in the presence of an externally applied electrical field. The iron impurities are nearly completely oxidized to the Fe^{3+} state. The concentration of Fe^{2+} is decreased by 4 to 5 orders of magnitude, compared to less than one order achieved with conventional oxidization. The oxidization starts at the cathode and forms a sharp front, which moves through the crystal. A model for the charge migration in the crystal during the treatment based on a step profile of the Fe^{2+} concentration is developed. It is experimentally verified by spatially-resolved absorption measurements and in-situ investigations of the electric potential distribution inside the crystal and the oxidation front velocity at different temperatures and doping concentrations.

*supported by the Deutsche Telekom AG

[1] M. Falk and K. Buse, Appl. Phys. B **81**, 853 (2005)