LASER PROGRAM

L.1 High-current-density pulsed electron emission from ferroelectric discs

High-current-density pulsed electron emission from ferroelectric materials is of much current interest due to its several advantageous features and a variety of potential applications. Lead zirconium titanate (PZT) and lead lanthanum zirconium titanate (PLZT) ceramics are the two most widely used materials for this purpose. Electron emission occurs due to polarization switching in ferroelectric materials. This is done in two ways, viz., 1) application of a high-voltage (HV) pulse across the two surfaces of a disc of ferroelectric material and 2) pulsed-laser irradiation of one of the end surfaces. The former method is referred to as field excited electron emission (FEEE) and the latter one as laser induced electron emission (LIEE).

Electron-emission pulses with a peak current density of the order of tens to hundreds of A / cm^2 and duration ranging from ~ 100 ns to ~ 1 μs have been observed in the presence of a DC extraction field. Self-emission of electrons (i.e. without a DC extraction field) has also been observed. The high-current-density electron emission is understood to be plasma assisted emission, which is formed on the ferroelectric surface, either due to the high electric field generated during polarization switching of the sample or due to occurrence of dielectric surface flashover.

In the case of LIEE, laser pulse durations ranging from 140 fs to 5 ns have been used. In contrast to this, in almost all the studies on FEEE from ferroelectric discs reported in the literature, HV excitation pulses of duration exceeding 100 ns were applied. This was considered to be necessary to achieve a high degree of polarization reversal in the ferroelectric sample, having polarization switching time of this order. However, use of HV excitation pulses of a few ns duration is desirable for the purpose of achieving unipolar excitation and to improve stability / lifetime of the ferroelectric cathodes.

At Laser Plasma Laboratory, we have been involved in experimental studies of electron emission from ferroelectrics. In order to study the feasibility of electron emission using short duration high voltage excitation pulses, investigations were carried out on poled PZT ferroelectric ceramic disks. Electron emission was observed from the surface towards the positive end of the polarization vector (i.e. the one with the surface screening electrons) by applying a 6 ns of HV excitation pulse either on the rear surface or on the front emitting surface, keeping the other surface at ground potential. Pulsed electron emission occurred with a current density ~ 400-450 A / cm^2 and FWHM duration of ~ 200-250 ns in the presence of a DC extraction field. Self-emission of electrons with a current density of ~ 20-30 A / cm^2 was also observed for both the configurations of application of the excitation pulse. The electron emission is understood to result from occurrence of partial polarization reversal in the ferroelectric sample followed by plasma formation on its surface. These observations bring out the usability of short duration (few ns) HV excitation pulses for FEEE from ferroelectric materials. [For more details: A. Moorti, P. A. Naik, and P. D. Gupta, IEEE Transactions on Plasma Science 32, 256, Feb. 2004].

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L.2 New techniques for sensitive detection and estimation of chirp and pulse asymmetry of femtosecond laser pulses

Generation and application of ultra-short laser pulses requires reliable characterization techniques to determine various pulse parameters like duration, shape, chirp, pulse front tilt etc. The response of electronic photo-detection systems is limited to a few ps for fast photo-detectors and to a few hundred femto-seconds for fastest streak cameras. However, they cannot be used for detecting chirp or pulse front tilt present in the ultra-short laser pulse. Hence, ultra-short laser pulses are characterized by indirect autocorrelation methods using slow electronic detectors for pulse duration of a few picosecond and smaller. While diagnostic systems such as single shot second order auto-correlators are widely used for measurements of pulse duration, angular chirp and pulse-front tilt of ultra-short laser beams, they cannot provide information on the pulse shape and any temporal asymmetry in the laser pulse. Therefore, many expensive diagnostic set-ups based on cumbersome correlation techniques are being used for detailed characterization of ultra-short laser pulses. Development of simple and inexpensive diagnostic systems, capable of real time characterization of ultra-short laser pulses and associated pre-pulses (if any) is, therefore, highly desirable.

In Laser Plasma Laboratory, we have worked on new techniques for sensitive detection and estimation of chirp and pulse asymmetry of femtosecond laser pulses. These are based on recording the interferometric auto-correlation signals in real time using a commercial grade audio speaker as a delay line and a commercial grade AlGaAs LED as a two-photon detector in a Michelson interferometer configuration. In the first technique, balanced interferometric auto-correlation (IAC) ["balanced" means pulse split up into two equal intensity pulses] has been used for estimation of various order chirp [*A.K. Sharma, P.A.Naik and P.D. Gupta, Opt. Commun. 233,431,2004*]. It is shown that post-processing of the balanced IAC signals by spectrum modification can give precise values of linear, quadratic and cubic chirp, if any, present in the pulse. However, this does not provide any information about pulse asymmetry.

We have also proposed a new method for sensitive detection and estimation of any asymmetry present in the pulse through unbalanced interferometric auto-correlations (U-IAC) ["Unbalanced" means splitting the main pulse into two unequal intensity pulses]. Here, the direction of time ambiguity in second order IAC signals is eliminated by unbalancing the intensities of the two interfering beams. It is shown that the sensitivity of the unbalanced IAC signals to pulse asymmetry can be significantly increased by modifying the spectrum content of the U-IAC signal [*A.K. Sharma, P.A.Naik and P.D. Gupta, Optics Express 12, 1389, 2004*].

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L.3 Towards new giant magneto caloric materials

Magnetic refrigeration has been used to produce ultra-low temperatures (T < 1K) since 1920s because of high efficiency (60%) of this technique compared with that (40%) of the conventional methods. But small magneto caloric effect (MCE) and low magnetic ordering temperatures of the working materials have prevented the wide application of this technique in the higher T region. MCE [isothermal change of entropy (S) or adiabatic temperature change in a material because of applied magnetic field (H)] has therefore been a subject of growing interest. Apart from addressing fundamental queries and enhancing the cost efficiency of refrigeration, today the interest in MCE is also driven by growing environmental concerns.

The most fundamental requirement for a potential MCE material is a large change of magnetic entropy (S_m) in an accessible applied magnetic field. According to the Maxwell's relation

$$\left[\frac{\partial S_m}{\partial H}\right]_T = \left[\frac{\partial M}{\partial T}\right]_H$$

a large change in S_m requires a strongly temperature dependent magnetization (M) which in general can happen in the vicinity of phase transitions. Therefore, better fundamental understanding of the relationship between magnetic phase transitions and MCE is absolutely essential for building the technology for magnetic refrigeration. First order magnetic transitions become even more important in this aspect as magnetization changes more abruptly in such transition as compared to transitions of higher order. Recent research has shown that certain compounds and alloys have a magneto-structural transition coupled to a first order phase transition (FOPT) in the H–T phase space. In such a material, application of magnetic field not only changes the magnetic entropy, but there is an additional change in entropy due to field-induced changes in lattice configuration. As a result such materials exhibit large MCE. LTPL, CAT, has been working on doped $CeFe_2$ compounds for quite some time and have made significant contributions [e.g., M. A. Manekar, et al, Phys. Rev. B 64 (2001) 104416; K. J. Singh, et al, Phys. Rev. B 65 (2002) 094419; M. K. Chattopadhyay, et al, Phys. Rev. B 68 (2003) 174404; S. B. Roy et al, Phys. Rev. Lett. 92 (2004) 147203] towards understanding the magneto-structural transition coupled to the H- and T- driven FOPT in these compounds. Magnetization (M), magneto-transport, and various metallurgical aspects of another compound Gd_5Ge_4 [which is the end compound of potential MCE material-series $Gd_5(Ge_{4-x}Si_x)$] are also being studied in LTPL, in order to understand the magneto-structural transition coupled to FOPT in this series of compounds. A major motivation for all these studies is to address some extremely important unsolved problems in the subject of MCE, e.g., how to improve the MCE in a series of alloys/compounds so as to get a large MCE at an affordable magnetic field; and finally, while designing a new MCE material, how to predict the probable MCE. Here, we present some of our recent results on the MCE of Ru doped $CeFe_2$ compounds.

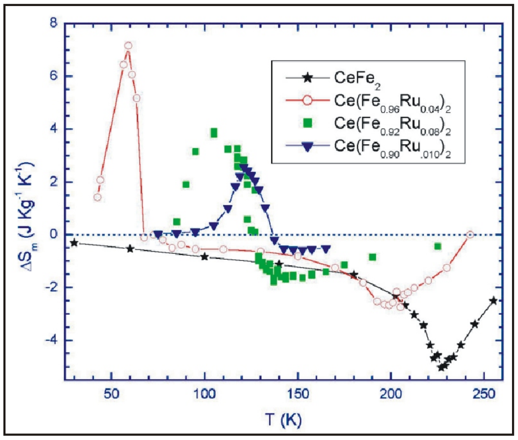

Fig. L.3.1 *Change of magnetic entropy as a function of temperature in Ru doped $CeFe_2$ alloys*

Fig. L.3.1 shows the change of magnetic entropy (ΔS_m) of $Ce(Fe_{1-x}Ru_x)_2$ pseudo-binaries as a function of temperature.