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.

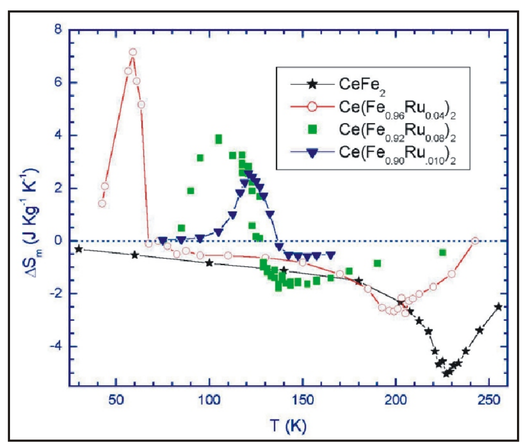

Fig. L.3.1 *Change of magnetic entropy as a function of temperature in Ru doped $CeFe_2$ alloys*

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.

Isothermal M vs. H data obtained at different temperatures using a commercial SQUID magnetometer. ΔS_m is calculated from the M-H curves using the formula,

$$\Delta S_m = \int_0^H \left[\frac{\partial M}{\partial T}\right]_H dH$$

ΔS_m is found to be positive across the first order antiferromagnetic to ferromagnetic transition (with rising T) observed in the present Ru doped $CeFe_2$ pseudo-binaries. This tells that if a magnetic field is applied adiabatically across the FOPT in the present series of alloys, the sample would undergo a reduction in temperature. On the other hand, ΔS_m is found to be negative across the second order ferromagnetic to paramagnetic transition (with rising T). The samples would therefore produce cooling during adiabatic withdrawal of magnetic field at various starting T across the second order transition. The largest magnitude of ΔS_m in the whole series of Ru doped $CeFe_2$ measured is found to be 7.16 J per kg per K, in $Ce(Fe_{0.96}Ru_{0.04})_2$, at about 60K, i.e., across the FOPT. The largest magnitude of ΔS_m across the second order transition is observed in undoped $CeFe_2$, which does not exhibit an FOPT. ΔS_m across the second order transition appears to decrease in magnitude with Ru doping. Further studies on the present series of alloys towards the quantitative estimation of adiabatic temperature changes with changing applied magnetic fields and the refrigeration capacity of the alloys in different temperature regimes is presently in progress. These along with the parallel studies on Gd_5Ge_4 being carried out in LTPL, are expected to provide substantial information in the direction of designing suitable working materials for energy efficient and environment friendly refrigerators.

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L.4 Laser rapid manufacturing of colmonoy-6 bushes

Colmonoy bushes are used as guiding material in many components of Prototype Fast Breeder Reactor (PFBR). Traditionally, these bushes are made by conventional casting process. However, the indigenous non-availability of cast bushes and prohibitive cost of imported bushes necessitated the development of alternative process for their fabrications. At present, these bushes are fabricated by depositing the hard facing alloy on austenitic stainless steel rods using Gas Tungsten Arc Welding (GTAW) process followed by precision machining. However, this process is cumbersome and time consuming, as it involves many steps of conventional processing, viz. welding, machining, grinding, etc. Therefore, another process is developed using Laser Rapid Manufacturing (LRM).

LRM is the process of fabricating near net shape three-dimensional components, directly from CAD model, by multi-layer overlapped laser cladding. Using a 10 kW CW CO_2 Laser system, integrated with co-axial powder feeding unit and 3-axis laser workstation, Colmonoy-6 bushes were fabricated with this technique. The Colmonoy alloy normally has very poor cracking resistance. However, cracks were avoided by processing at an elevated temperature (673 K) and subsequent controlled cooling.

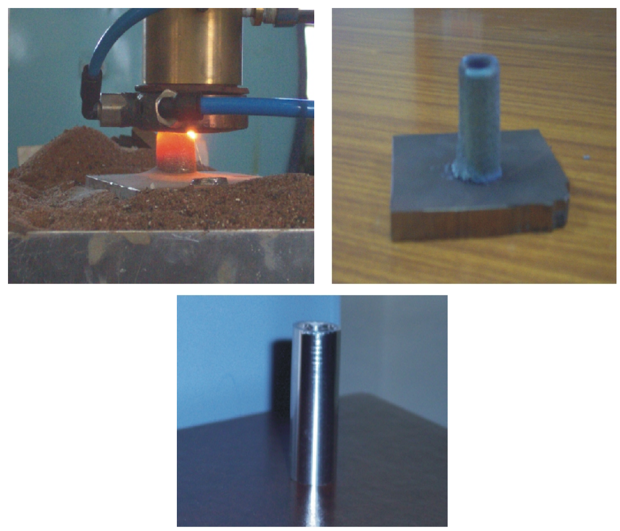

Fig. L.4.1 *Different stages showing laser rapid manufacturing of Colmonoy bush*

The LRM fabricated bushes are then machined using Cubic Boron Nitride (CBN) tools to achieve desired dimensional tolerance of H7/h6 grade and surface finish of 0.4 micron. Testing of these bushes by various characterization techniques e.g. dye-penetrate test, Ultra-sonography, micro hardness, metallographic examination, ageing experiments for 24 hours etc., confirmed their quality at par with those made by GTAW technique.

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L.5 Enhancement of intergranular corrosion resistance of 316(N) weld metal by laser surface resolidification

AISI type 316LN stainless steel (SS) has been developed indigenously as main structural material for 500 MWe Prototype Fast Breeder Reactor (PFBR) at Kalpakkam. Welding of type 316LN SS is to be carried out with modified