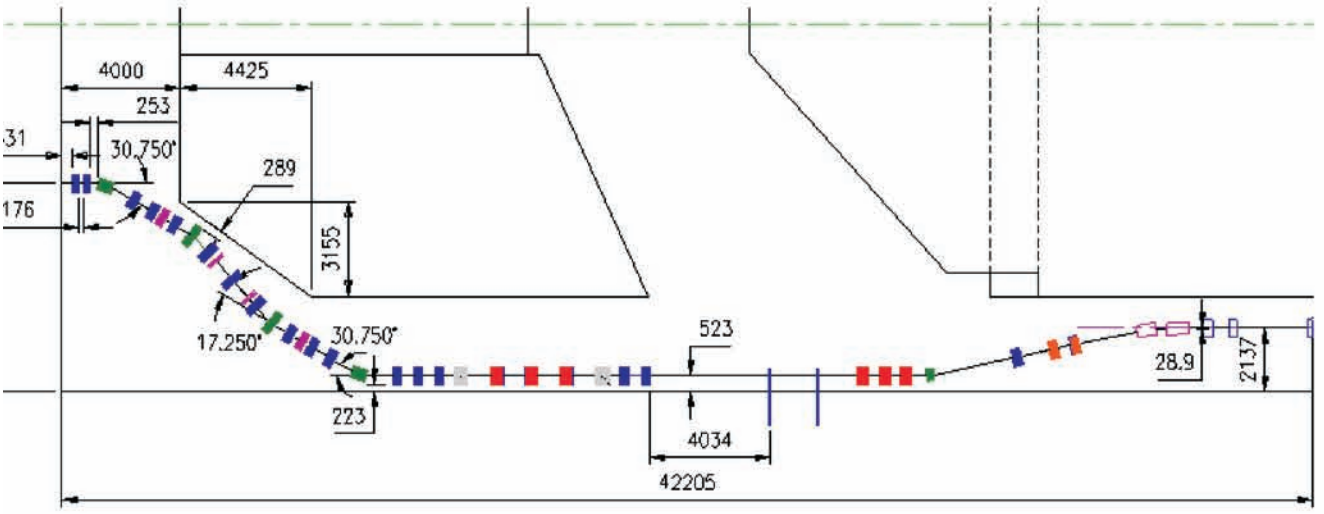

Fig.A.2.1: Schematic layout of TL-2

between the module-1 and module-3. This module has a clear dispersion free space of nearly 4 m for placing the tail clippers, another clear space of nearly 3 m to facilitate the operation of the emergency gate, and a vertical achromat for sending the electron beam 50 cm downwards.

The third module, the most complex of the three, is a R_{56} tunable achromatic arc. It also has a final matching quadrupole doublet to send a beam with proper parameters to the CLEX area. There are four dipole magnets in the arc, out of which two will be used to make the arc achromatic, and other two for tuning R_{56}. For controlling the T_{566}, there are four sextupole magnets in this module. Wide tuning of R_{56} is obtained by varying the dispersion distributions. A consequence of this is that, there is a drastic variation in betatron phase advances as R_{56} is varied from -0.30 m to +0.30 m, and this causes a large change in the lattice parameters at the location of the sextupoles. So, any standard sextupole scheme, such as *-I* transformer scheme, cannot be applied for the entire tuning range to minimize the effects of sextupoles on emittance dilution. These difficulties have been overcome with a computer program developed for optimizing the lattice parameters at the location of sextupole magnets.

The optics design of this line, meeting all the required specifications, has been done and communicated to CERN in July 2007.

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A.3 : Imaging of dynamics of a first order magneto-structural transition using magnetic force microscopy

Fe-Rh alloy is an interesting system showing giant magnetocaloric effect (change in temperature of the sample due to applied magnetic field), giant elastocaloric effect (change in temperature due to external stress), giant magnetostriction (change in volume due to applied magnetic field) and giant magnetoresistance (change in resistance due to applied magnetic field) occurring close to room temperature. Such wide range of functionality of this alloy system arises due to a first order magneto-structural transition (FOMST) from an antiferromagnetic to ferromagnetic state which takes place both as a function of temperature and magnetic field. While most of the attention has been focused on the microscopic origin of the transition, the possible role of phase coexistence across the FOMST in tuning the functional properties of this material has largely gone unnoticed. Magnetic and Superconducting Materials Section of RRCAT in collaboration with Laser Systems Engineering Division of RRCAT have directly imaged the time evolution of the magnetic and the accompanying structural transition in Fe-Rh alloy at room temperature using magnetic force microscopy (MFM).

Figure A.3.1 shows a 6 μm x 6 μm area of the Fe-Rh sample. The sample, which is in the antiferromagnetic state in the temperature region below 290 K, was brought back to room temperature after exposing to liquid nitrogen (77 K). With this temperature history, the sample is mostly in the superheated antiferromagnetic state at room temperature. This can be seen from MFM image (M0) where there is

almost no magnetic signal. To study the time evolution (dynamics) of the antiferromagnetic to ferromagnetic transition, the attention is focused on the place marked as "A" on the 3D topography and the MFM image. At time t = 0 (i.e. the first measurement performed after bringing back the sample to room temperature), the place marked "A" on the topography (T0) has a height of about 40 nm and is the largest defect site on the surface. This defect site acts as a nucleation centre for the first nucleus of the ferromagnetic phase. The images (T1) and (M1) were obtained after 1 hour. As can be clearly seen, the magnetic signal (ferromagnetic state) at location "A" has increased to slightly more than 4^0. The antiferromagnetic to ferromagnetic transition is also coupled to a structural distortion in which the volume of the unit cell in the ferromagnetic phase is slightly larger. Correspondingly, the height of the location "A" has also increased to slightly more than 50 nm [see (T1) in Fig.A.3.1].

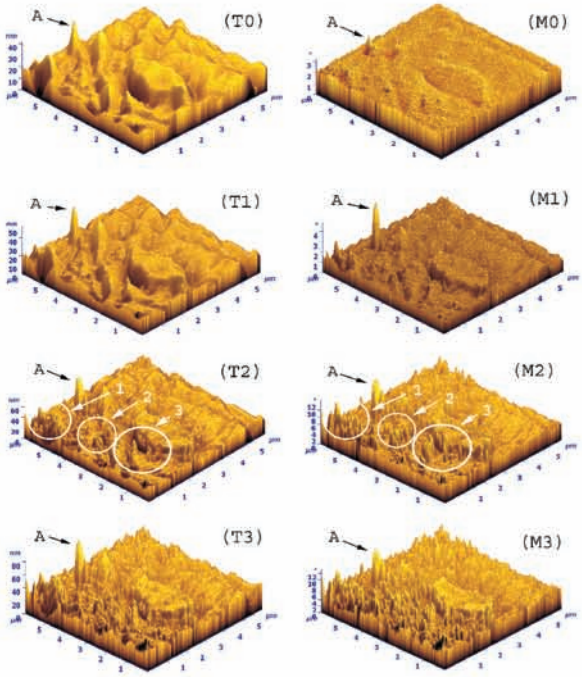

Fig. A.3.1: Time evolution of topography (T0, T1, T2 and T3) and the corresponding magnetic information (M0, M1, M2 and M3). Note the change in scale of the MFM images between M1 and M2, indicating the rise in magnetic signal.

The topography (T2) and MFM (M2) were again recorded after another 1 hour (t = 2 hrs). New *blisters* appear on the topography and the MFM image. These regions are marked as 1, 2 and 3. At t = 2 hrs, the height of the location "A" has also increased to almost 70 nm with a corresponding increase in the magnetic signal at the same location. This observation shows that not only the growth of individual nucleus but also the formation of newer nuclei is governed by intricate coupling between the surface topography and the magnetic structure. Eventually after 3 hours, almost entire sample surface gets crowded with these nuclei of the product ferromagnetic phase ((T3) and (M3)). These results can be interpreted in terms of an intricate coupling between the electronic and elastic degrees of freedom.

In conclusion, direct imaging of the time evolution of initial stages of a first order magneto-structural transition occurring in Fe-Rh alloy has been done. Coexistence of antiferromagnetic and ferromagnetic phase in the sub-micrometer scale is observed. This phase-coexistence, which can be manipulated by applying an external magnetic field or stress, plays a crucial role in the functional properties like, giant magnetocaloric effect, giant elastocaloric effect, giant magnetostriction and giant magnetoresistance of this material. [See for details : M. Manekar, C. Mukherjee and S. B. Roy *Europhysics Letters*, 80, 17004 (2007).]

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A.4 : Magnetocaloric effect in MnSi

The heating or cooling of a magnetic material because of a variation of applied magnetic field (H) is generally referred to as the magnetocaloric effect (MCE). MCE is intrinsic to all magnetic materials. It results from the coupling of a magnetic sublattice with the magnetic field, which changes the magnetic part of the entropy of the material. Materials showing large MCE below 70 K are potential magnetic refrigerants for gas liquefiers. They are also potential "passive" magnetic regenerators for hybrid refrigeration cycles. Recently, we have probed the intermetallic compound MnSi for its MCE characteristics below 70 K. MnSi is an itinerant helimagnet having ordering temperature (T_{ord}) just below 30 K. It is known that the application of magnetic field on MnSi at temperatures below T_{ord} leads to successive field induced phase transitions starting from the zero and low field helimagnetic state to a state with conical spin structure, and then to a high field ferromagnetic state. The temperature gradient of magnetization (M) is expected to be large across a magnetic phase transition. The change of magnetic entropy due to applied field is directly related to this temperature gradient of magnetization. Thus MCE is likely to be large near a magnetic phase transition, and this was the motivation to study the MCE in MnSi around T_{ord} at the Magnetic and Superconducting Materials Section of RRCAT.