Probing the ultrafast response of invar alloys with a pump and probe x-ray diffraction study

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In 1897 Guillaume showed that a $Fe_{0.64}Ni_{0.36}$ alloy have almost constant thermal expansion in a wide region of temperatures and quantitatively this would represent values 10 times smaller than the one found for metals. This effect, denominated Invar by its discoverer, is most usually described by a so called 2γ-state proposed by Weiss. Pump and probe experiments provide important information on the dynamics of fast phenomena. With the possibility of attaining picosecond X-ray pulses, beamlines at synchrotron sources equipped with choppers are an important tool to study the Invar problem. Our pump and probe experiments were done in a series of measurements, both at the ID9 beamline of the ESRF and the NW14A beamline of the Photon Factory KEK synchrotron facility. The laser in both cases was adjusted to a high energy density of 800 uJ/pulse with a repetition rate of 1 kHz.

As we measured a bulk sample polycrystalline Invar in the γ phase, we had to use a grazing incidence geometry in order to match the probed volumes by the 800nm laser pulse and the 15keV X-ray pulse. The diffraction pattern was collected by a CCD detector, both images with the laser on (excitation) and with no laser (steady state) were collected for several time delays and those images were processed to yield a graph of the peaks as a function of either 2θ or q.

During the experiment done at KEK we studied a thin film of invar (50nm thickness) thermally treated to reach the γ phase. For that reason the matching volume condition was satisfied out of the grazing incidence condition, necessary for the bulk sample, and allowed the incident angle to be modified to 8^{o}. In addition we also investigated the effect of the power delivered at the sample by the laser, this is important because is directly associated to the temperature and consequently is a measurement of the thermal expansion cofficient.

Our preliminary analysis show that in the high laser power regime for the bulk and the thin film of invar there is a response to the temperature rise triggered by the laser followed by a thermal relaxation of the order of nanoseconds. At the low laser energy regime the thermal expansion coefficient analysis points to a non invar behavior at the time scales of picoseconds.