Influence of tensile stress on the surface magneto-optical hysteresis loops in amorphous and nanocrystalline ribbons

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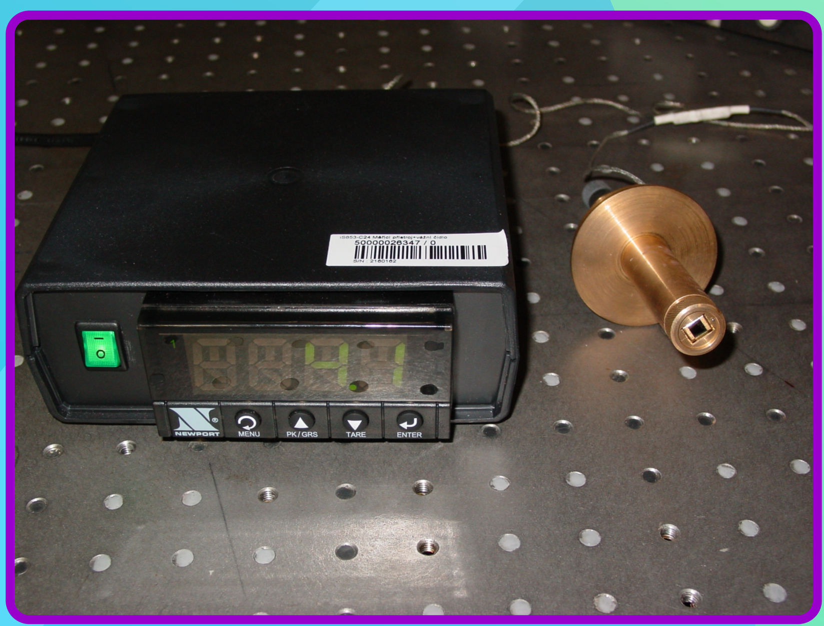
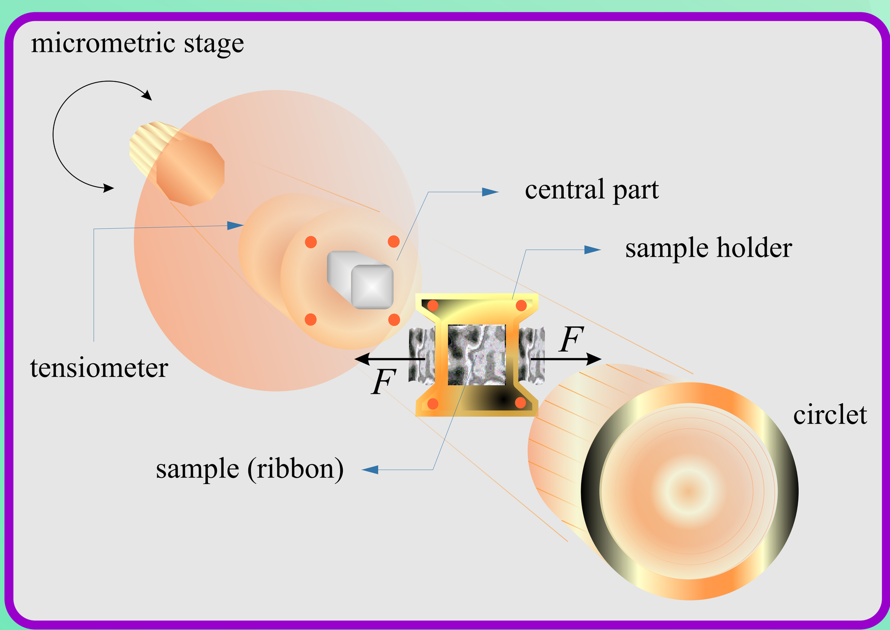
Objectives

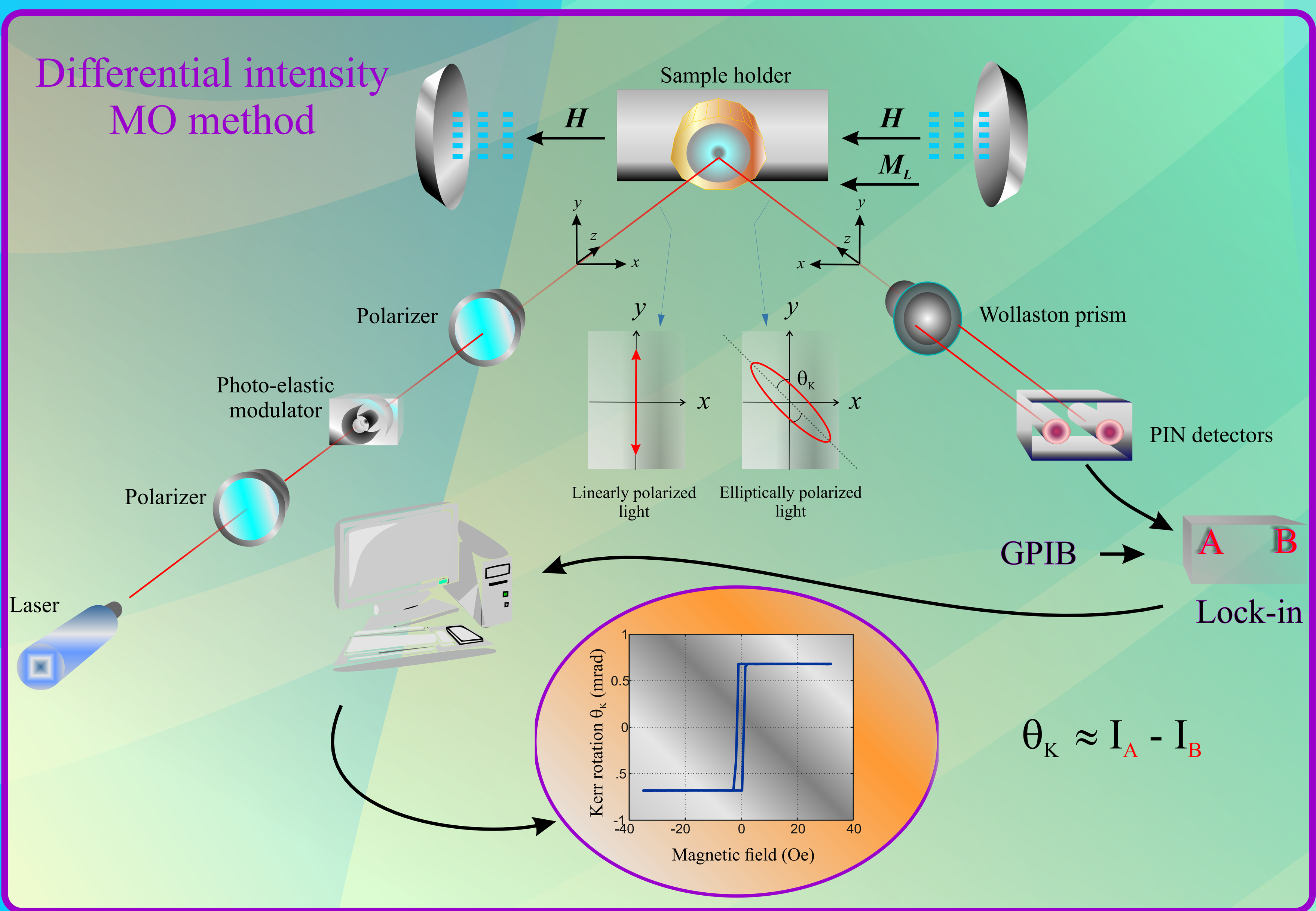
- The fabrication of the special sample holder, as a part of the magneto-optical (MOKE) differential intensity setup, enabling to apply the tensile stress in the axis of amorphous and nanocrystalline ribbons prepared by the planar flow casting (PFC) method.
- The investigation of the influence of tensile stress on the ribbons surface magnetic properties and magnetic anisotropy using the MOKE hysteresis loops.
- The practical demonstration of the holder in the case of field-annealed $Co_{66}Fe_4Si_{15}B_{15}$ and as-quenched $Fe_{77.5}Si_{7.5}B_{15}$ ribbons.

Principle of operation





- The sample (ribbon) is placed in specially designed non-magnetic sample holder and is fixed by screwing the circlet with the hole in the middle (for incidence and reflection of the light).
- Rotation of the micrometric stage causes the movement of the central part of the holder in the forward and backward directions. In this way the tensile force F in the range of 0 - 50 N can be applied in the ribbon axis.
- Actual value of the force is monitored by the tensiometer and displayed by the digital controller.



- As a source of light we employed the red laser diode (λ = 670 nm) modulated at frequency of 100 kHz.
- Due to the Frank -Ritter polarizer the light that incidents the sample surface is linearly polarized (s or p).

The reflected light goes through the Wollaston prism that divides the incident light into two orthogonal linearly polarized beams.

Both beams are detected by two PIN photodiodes and their differential signal is proportional to the MO angle of Kerr rotation θ_K.

- Measured surface hysteresis loops depict the Kerr rotation plotted versus the magnetic field H.

Calculation of magnetostriction coefficient λ_S

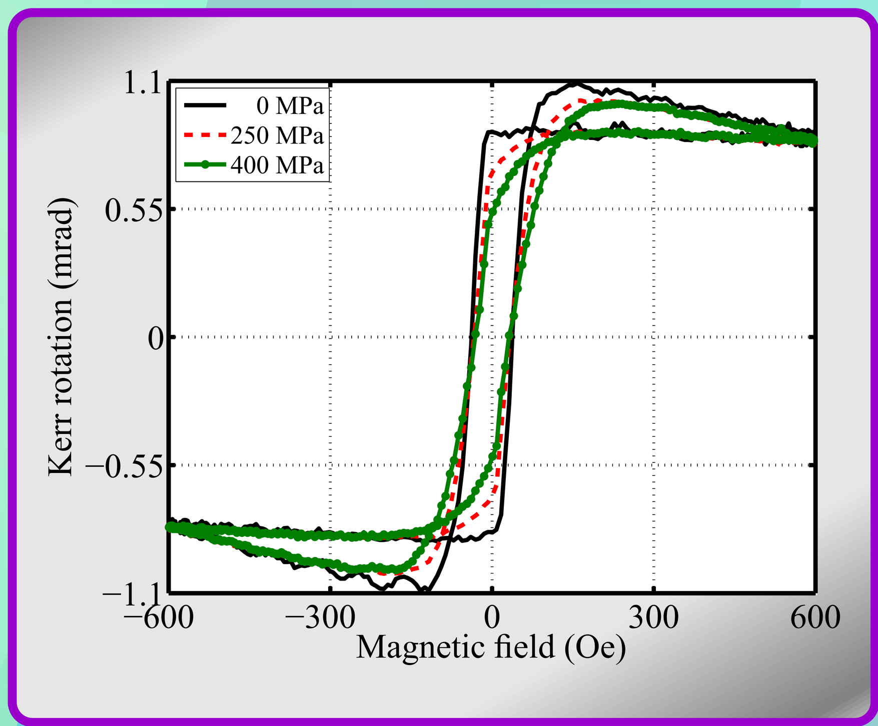
$$\lambda_S = \frac{J_S (H_{A0} - H_A)}{3\sigma} = \frac{J_S (H_{A0} - H_A) S}{3F}$$

H_{A0} effective anisotropy field without applied stress (Oe = $10^3/4\pi$)
H_A effective anisotropy field with applied stress (Oe = $10^3/4\pi$)
σ = F/S applied stress (Pa), F ~ 0 - 50 N
J_S magnetic polarization (emu.cm^{-3} = $4\pi \cdot 10^{-4}$ T)

Results

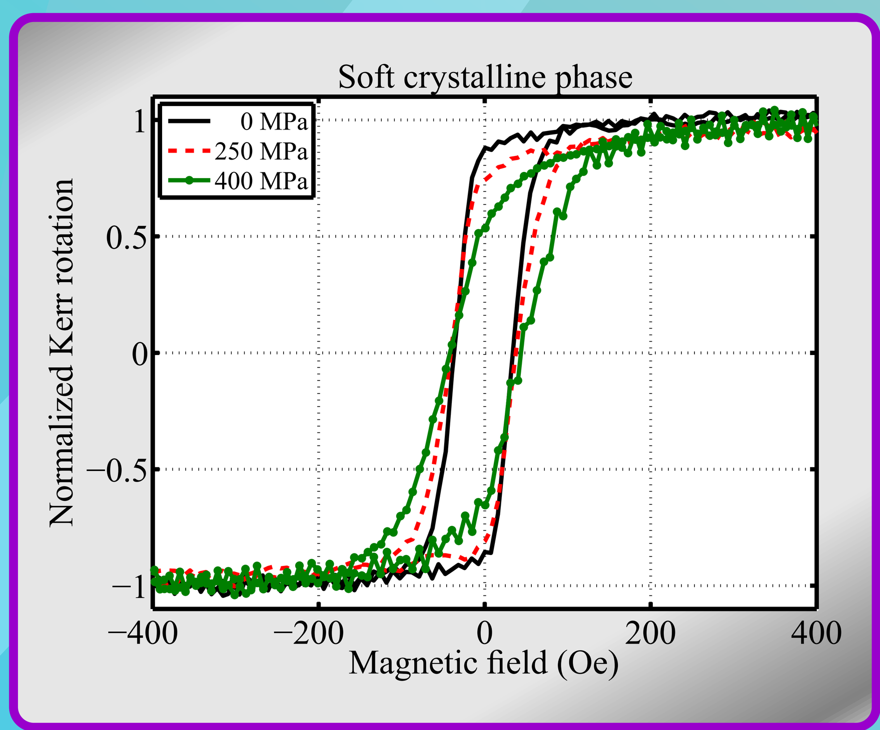
Field-annealed $Co_{66}Fe_4Si_{15}B_{15}$ ribbons

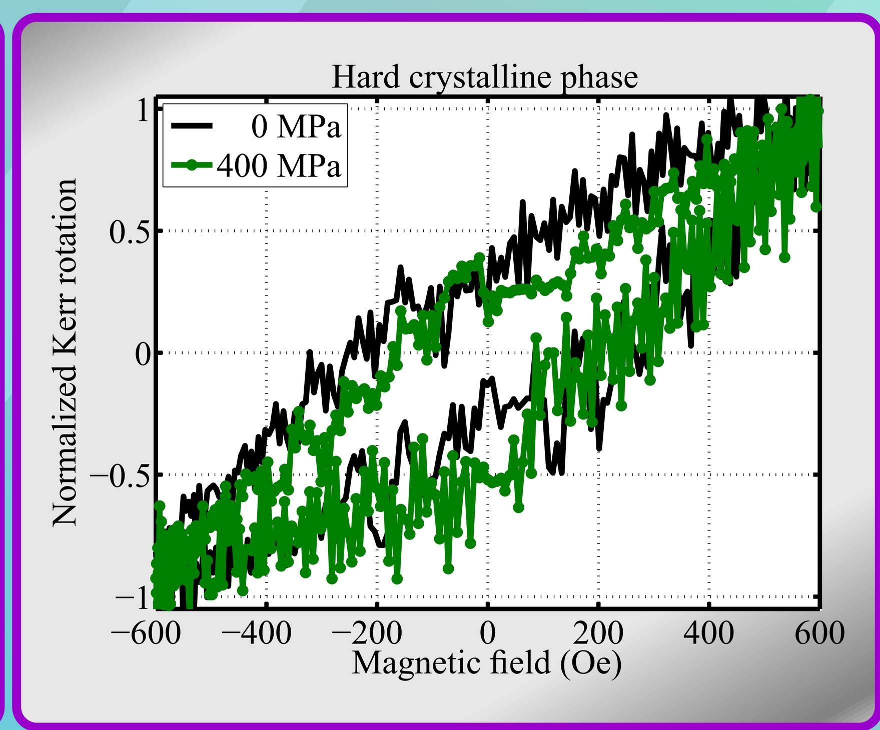
- 1 mm wide and 20 μm thick, prepared by the PFC technique
- annealed for 8 h at temperature of 380°C, magnetic field of 3 Oe was applied along the ribbon axis
- value of bulk magnetostriction : $\lambda_s = +2{,}1\cdot10^{-7}$



- Surface hysteresis loops of field-annealed CoFeSiB ribbons as a function of applied tensile stress σ measured on the shiny side.
- Detection of two magnetically hard crystalline phases.
- The separation of both phases due to the material (different response coming from both phases) or depth (incident light changes the phase due to the existence of the surface oxide layer originated after ribbon annealing) sensitivity.

The influence of tensile stress on the separated individual phases:





- Soft crystalline phase consists mainly of Co(Fe)Si crystallites.
- While stressed, the slope of loop decreases indicating the negative magnetostriction. ($H_{A0} < H_A$)
- The value of coercive field about 50 Oe.

Hard crystalline phase consists mainly of Co(Fe)B crystallites.

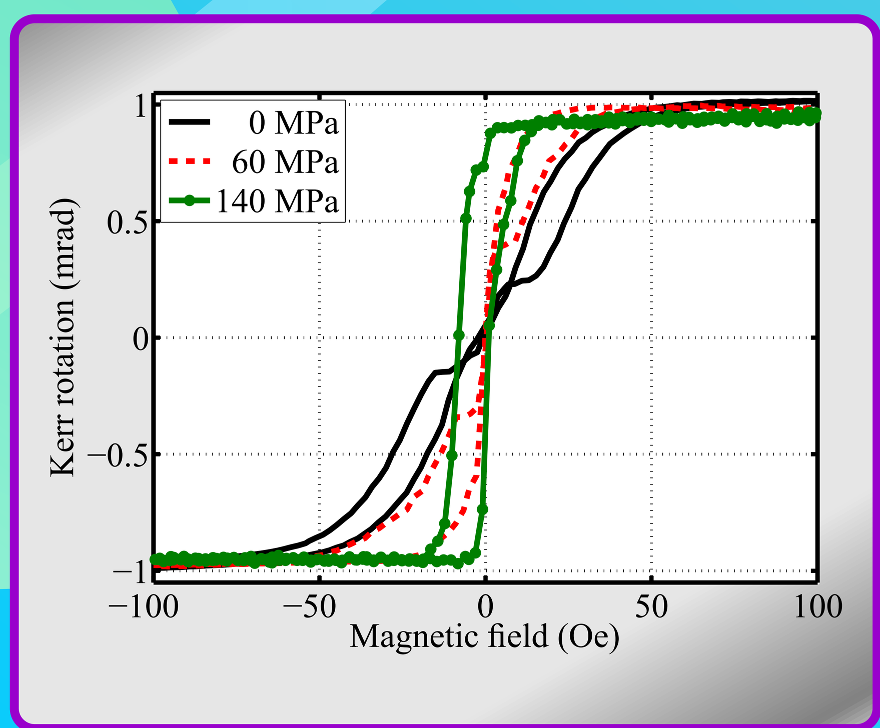
Practically no response from the applied stress, magnetostriction coefficient substantially lower. ($H_{A0} \sim H_A$)

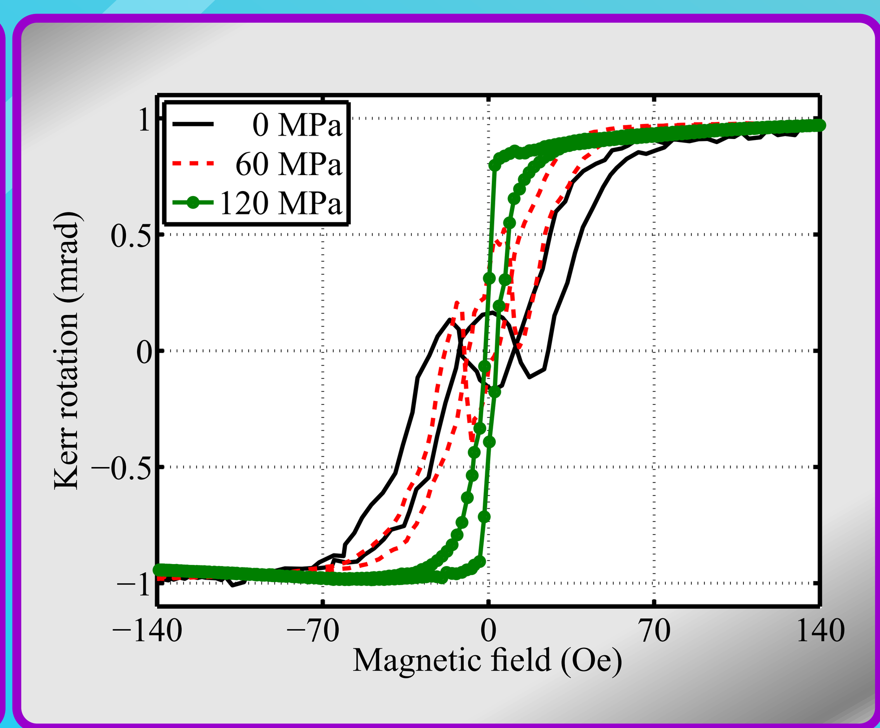
The value of coercive field higher than 200 Oe.

As-quenched $Fe_{77.5}Si_{7.5}B_{15}$ ribbons

- 5 mm wide and 20 μm thick, amorphous in the bulk as well as on both surfaces
- value of bulk magnetostriction : $\lambda_s = +3{,}2\cdot10^{-5}$

The influence of tensile stress in two different places on the surface:





- Two magnetic phases, FeSi and FeB clusters, are clearly visible at loop measured without loading.
- With increasing tensile stress the changes in anisotropy, demonstrated by increasing slope in MOKE loops of both phases, are detected.
- For σ = 140 MPa the preffered axis of both clusters has the direction parallel to the applied stress and magnetic field.
- Calculated values of λ_s of both phases (tens of ppm) are well comparable with the bulk magnetostriction.

Different shapes of MOKE loops in comparison to the first place.

Anisotropy and magnetostriction of both phases differ in every place on the surface, where the light is focused.

For σ = 120 MPa the clusters are already not distinguished at measured loops and magneto-elastic effect slowly saturates..

Positive magnetostriction of both phases is observed also in this place.