ESRF	**Experiment title:** High resolution X-ray diffraction of Nb_3Sn superconducting wires under applied mechanical stress at RT and 4.2K.	**Experiment number**: MA-737
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Report:

X-ray diffraction measurements have been performed on Nb_3Sn superconducting wires under applied mechanical stress at 4.2 K. Main aim of the experiment was to measure the elastic strain of the Nb_3Sn phase inside the structure of the composite wires. This could be done, by determining the lattice parameters along different directions as a function of an externally applied axial tensile load.

The following set of samples, characterized by different layouts and/or production techniques, has been measured: two bronze route type Nb_3Sn wires; two different internal-tin type Nb_3Sn wires, with either a single Ta diffusion barrier between the superconducting filamentary zone and the stabilization copper, or with a distributed Nb barrier. For the internal tin strands, the Nb_3Sn lattice parameters were determined on the bare strands, as well as on strands pre-compressed inside a stainless steel matrix (jacketed strands), in order to better simulate the behaviour of superconducting wires inside Cable-in-Conduit conductors. In addition, the same procedure was applied to wires with an untwisted filaments structure, in order to clarify the possible role of filament twisting on the mechanical behaviour of the system.

The experiment was made possible, thanks to a probe that was developed and assembled at the University of Geneva, which allows to carry out accurate measurements of stress vs. strain curves of wires in liquid helium, and adapted to a glass cryostat, thus allowing the characterization by X-ray diffraction at the High Energy Scattering beamline ID15B of the ESRF. In particular, diffraction measurements have been performed in transmission geometry, with diffraction pattern recorded with an area detector, thus allowing the characterization of crystalline planes oriented both perpendicular and parallel to the applied load.

For each sample, after a dedicated set of calibration runs, aimed at determining with accuracy the sample positioning and tilting with respect to the beam, as well as the detector distance, the diffraction spectra were acquired at each step of an applied axial tensile load, from zero, up to a maximum corresponding to irreversible sample degradation. At each step, the strain was measured by an extensometer, with respect to

the initial zero state (no applied load), corresponding to the thermal pre-compression acting at the Nb_3Sn level. The diffraction patterns were acquired with the sample probe rotated at 0° and 180° with respect to the beam, in order to minimize misalignment errors and remove any sample movement error. Each measurement result is thus the average of the two acquired spectra.

The lattice parameter has been determined for all samples, as a function of the applied axial strain, and for all the elements constituting the multi-filamentary wire: Nb_3Sn, Nb, Cu, and bronze. From the lattice parameters, the internal elastic strain corresponding to the externally applied load, was determined. Some loading-unloading cycles were also applied, at different levels of applied axial stress. All the stress-strain curves were also recorded during the measurement. For each element, different diffraction peaks have been analyzed, to check the consistency. A good agreement has been found among the various diffraction peaks.

Figure 1 reports the 2Θ diffraction spectra corresponding to the Nb_3Sn (200) peak in the direction parallel to the applied load, acquired at different values of axial strain, for an internal tin strand with distributed Nb barrier. As one can see, the increase of the lattice parameter corresponding to the application of the tensile load can be clearly identified in the shift of the peak to lower angles.

Figure 2 shows the Nb_3Sn lattice parameter, as determined from the (200) peak, in the directions parallel (axial) or orthogonal (transverse) to the applied load. Measurements of the bare strand and of the stainless steel reinforced one (jacketed) are compared. Such plot allows one to determine the value of the compressive pre-strain (ε_m) due to the differential thermal contraction of the various materials within the strand cross-section, which is about -0.1% for the bare strand, and about -0.6% for the stainless steel reinforced one. The data also clearly put into evidence the strain threshold above which Nb_3Sn yields. As one can see, a larger strain range is allowed for the stainless steel reinforced wire. In addition, the intersection among the curves of the lattice parameters in the axial and transverse direction determine the level of applied strain at which the Nb_3Sn lattice cell is cubic, whereas a lattice distortion is evidenced at the zero applied strain level. This very important information will be compared with what found experimentally in terms of transport critical current as function of axial strain. In particular, the peak in the characteristic curve of Nb_3Sn wires critical current vs. axial strain should correspond to this level of applied strain. This comparison will shed light on the transport mechanisms in Nb_3Sn based system subject to three-dimensional strain components. In spite of the fact that data analysis is still on going, these preliminary results show that the technique is appropriate and very promising for this type of characterizations.

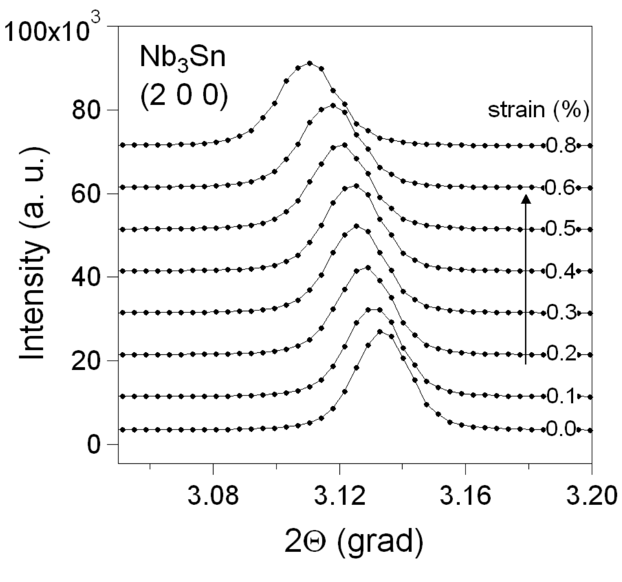

Fig. 1. 2Θ diffraction spectra corresponding to the Nb_3Sn (200) peak in the direction parallel to the applied load, acquired at different values of axial strain, for a bare, internal tin strand characterized by a distributed Nb barrier.

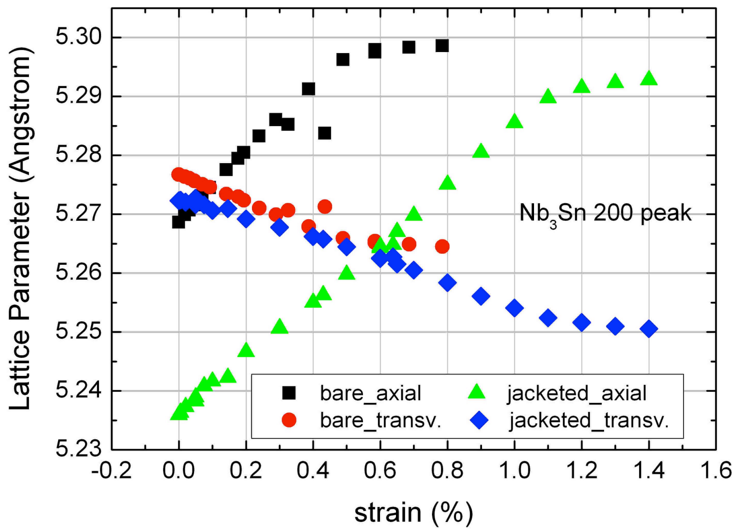

Fig. 2. Nb_3Sn lattice parameter, as determined from the (200) peak, in the directions parallel (axial) or orthogonal (transverse) to the applied load. Measurements of the bare strand and of the stainless steel reinforced one (jacketed) are compared.