ESRF	**Experiment title:** Acoustic properties of softwoods and their biological diversity: Why is Norway spruce superior for musical instruments?	**Experiment number**: SC−704
Beamline: ID13	**Date of experiment**: from: 07/04/00 to: 10/04/00	**Date of report**: 28/02/01
Shifts: 9	**Local contact(s)**: Martin Müller	*Received at ESRF:*

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Report:

Among a great variety of softwood species, Norway spruce (*Picea abies*) and more recently Sitka spruce (*Picea sitkensis*) have been evaluated as superior to be used for e.g. Violins and pianos. The origin of this specific character, however, remains to be answered.

A possible explanation might be found in the micro− and mesoscopic structure of wood cell walls. The tilt angle of the cellulose microfibrils with respect to the longitudinal cell axis (MFA) is of primary importance for the mechanical properties of wood. A low MFA means a high longitudinal elastic modulus *E*. The velocity of sound v_s (and therefore the acoustic properties) is directly related to the specific elastic modulus ($v_s = \sqrt{E/\rho}$). Both *E* (via the MFA) and density ρ vary in an annual ring of a tree from earlywood (low density) to latewood (high density). The aim of the experiment was to measure the seasonal variation of the MFA in different softwood species and set it in relation with acoustic properties determined in the laboratory. − In a second part of the experiment the local MFA variation around pit apertures was determined (see next page).

The ID13 scanning set−up with focussing glass capillary was used (wavelength 0.78 Å). The beam size at sample position was about 3 microns. Diffraction images were recorded on a Photonic Science CCD Detector (1024 x 1024 pixels of 27.6 x 27.6 μm^2). The equatorial $110+1\bar{1}0$ and 200 cellulose reflections were used to evaluate the local orientation of the cellulose fibrils. The data were processed using fit2d.

Thin radial sections (thickness 20 μm) of 24 different softwood species (including Sitka spruce) were investigated. For each sample, the MFA was determined from the fibre diffraction diagrams of the radial walls in a number of tracheid cells in both earlywood and latewood. In agreement with textbooks, the MFA in earlywood was always found to be higher or equal to the one in latewood. Fig. 1 shows the measured velocity of sound versus the difference of the MFAs (earlywood − latewood) for part of the samples (preliminary results). There is no clear trend visible, and Sitka spruce seems to have no special properties in this respect. Data analysis is still in progress.

The local orientation of cellulose fibrils around pit apertures was investigated in Norway spruce wood (*Picea abies*) samples with different mean microfibril angle as determined by small−angle X−ray scattering in the laboratory beforehand. In *Picea abies*, the pit apertures that connect tracheids and cross−running ray parenchyma cells are slit−like and inclined versus the cell axis by an angle that has often been related to the microfibril angle. In order to investigate the local fibril orientation, 10 µm thick tangential sections of spruce wood containing at most one pair of single cell walls were scanned across the beam in steps of 5 µm.

In Fig. 2 results from a linear scan across several cells of compression wood (lower side of a Norway spruce branch) are shown. The local fibril orientation is plotted versus position (Fig. 2b). Note that the fibrils are seen in projection and the measured orientation therefore varies between 0° in the walls parallel to the beam and μ_{max} in the walls perpendicular to the beam, where μ_{max} corresponds to the true angle. Fig. 2 shows that in compression wood the cellulose fibrils approximately follow the orientation of the pit apertures (see the polarized light microscope image, Fig. 2a). A similar agreement between the orientation of cellulose fibrils and of pit apertures was found also in latewood with mean microfibril angles of 0° and 20°. Quite on the contrary, in earlywood with a mean microfibril angle of 0°, the pit apertures were tilted by about 30° versus the cell axis. The present microdiffraction experiment showed that in the pit region, the cellulose fibrils locally do follow the pit apertures, but outside the pit region, but still within the same wood cells, the cellulose fibrils were oriented almost vertically. A publication on these results is in preparation.

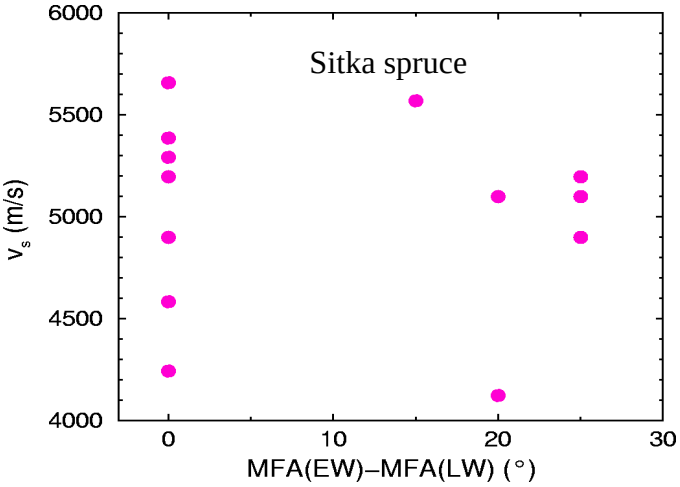

Figure 1:

Velocity of sound vs and difference of MFA for earlywood (EW) and latewood (LW) for different softwood species. No clear trend is visible.

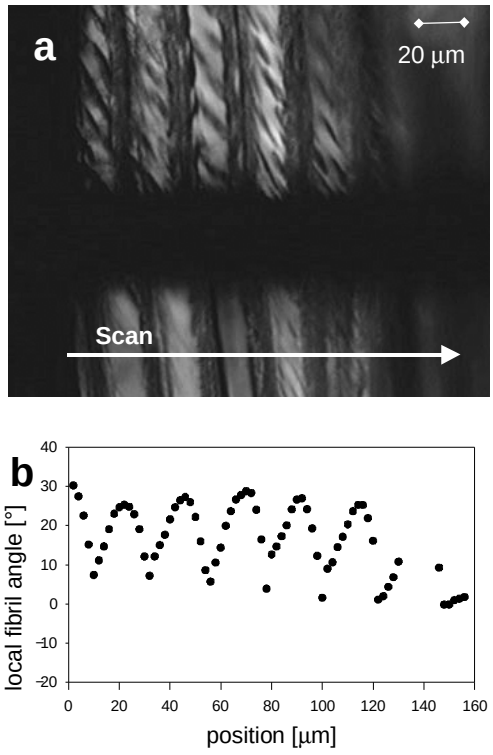

Figure 2:

(a) polarized light microscope image of single Norway spruce wood cells (compression wood) in tangential section. The slit−like pit apertures can be seen in the upper part of the image.
(b) microdiffraction data from the scan indicated in (a). The plot is scaled such that positions exactly correspond to positions in the micrograph above. One can see that the local fibril angle is about 25° (peak amplitude), which corresponds well with the tilt angle of the pit apertures versus the longitudinal cell axis.