DETERMINATION OF LIGHT TRANSMITTANCE IN FRENCH LOCAL TREE SPECIES

Juliette Boivin[1(*)], Louis Denaud[1], Stéphane Girardon[1], Damien Teyssieux[2], Luc Froehly[2]

[1] Arts et Metiers Institute of Technology, LABOMAP, HESAM Université, F-71250 Cluny, France
[2] Franche-Comté Electronique Mécanique Thermique Optique (FEMTO-ST), Besançon, France
[(*)] *Email:* juliette.boivin@ensam.eu

ABSTRACT

Wood is a multi-structural material with properties depending on its growing conditions. This variability is considered in industry through different non-destructive testing methods. Among them, the use of lasers to detect fibers orientation with different wavelengths. Our objective in this paper is to realize transmission light scattering maps for wood samples from several wood species, and then identify the most suitable wavelength to study light diffusion in wood. It was found that near-infrared light better scatters in the wood species we studied than lower wavelength. However, the wavelength that gives the best contrast between earlywood and latewood depends on the sample studied and is not necessarily in the near infrared rays.

Keywords: Light diffusion, optics, tracheid effect, image processing, wood.

INTRODUCTION

The natural variability of wood material and its multi-scale structure (Schoch 2004, Trouy 2015) makes it more complex to industrialize than other materials. In particular, woods which grew up in temperate regions are more likely to have knots or defects. One of the most important parameter of wood heterogeneity is the orientation of its fibers, which governs its mechanical and physical properties. The knowledge of this orientation for a veneer or a sawing can improve its use. These characteristics can be measured using non-destructive methods.

Nowadays, this measurement can be realized thanks to the tracheid effect (Briggert 2018, Kienle 2008, Nyström 2003), using lasers: when a laser beam illuminates a wooden surface, the light is scattered and leads to a halo of light with an elliptical shape whose major axis follows the wood fibers (Fig. 1).

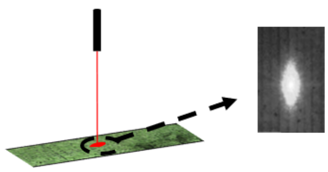

Fig. 1 – Illustration of tracheid effect

This phenomenon, which is inexpensive to instrument, can be used to develop models of mechanical and drying behavior. However, the parameters involved in obtaining the tracheid effect and their respective influences have been little studied for the moment.

The aim of this work is to determine the physical and mechanical properties which have an influence on the tracheid effect in order to better exploit it in the industry as for example for the mechanical classification (Besseau 2021).

The first stage is to determine the effect of the laser parameters (wavelength, power, focus...) on the tracheid effect obtained, in order to be able to obtain a pronounced tracheid effect and to be able to exploit it as well as possible. In particular, we will measure the transmittance of different types of wood in order to determine the wavelength that transmits the best in a general way, in order to use it in our later experiments.

In the following section, the wood samples used and the different elements of the set-up used to make the measurements are presented. The first results obtained are then presented and their representativeness and reliability are discussed.

MATERIAL AND METHODS

Wood samples

The selected species are beech (*Fagus Sylvatica*), Douglas fir (*Pseudotsuga menziesii*), poplar (*Populus*), and oak (*Quercus*). These are species growing in France, chosen to cover a range of microstructures in order to be able to link the observations to their microstructure.

Two different grain orientation are studied, radial and tangential (Fig. 2).

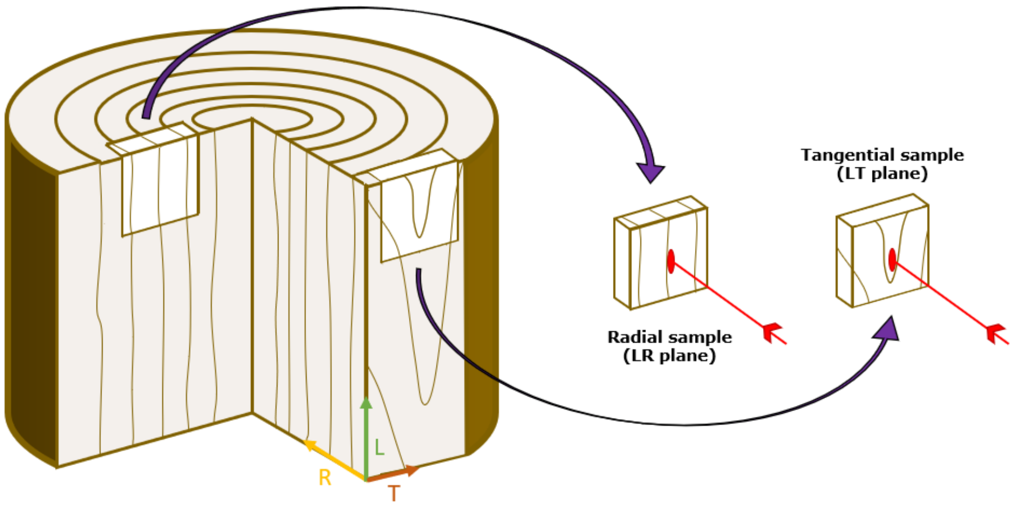

Fig. 2 – Representation of the orientation of the samples used and the orientation of the laser beam incident on them

For each of the two orientations and four species, two planed wood samples respectively of size 50 x 50 x 1mm and 50 x 50 x 3 mm were processed, providing a total of 16 samples.

Presentation of the set-up

The experimental set-up shown in Fig. 3 was carried out to measure the transmittance of the wood samples. Transmittance is defined as the ratio of the luminous flux before passing through the sample and the luminous flux after passing through the sample.

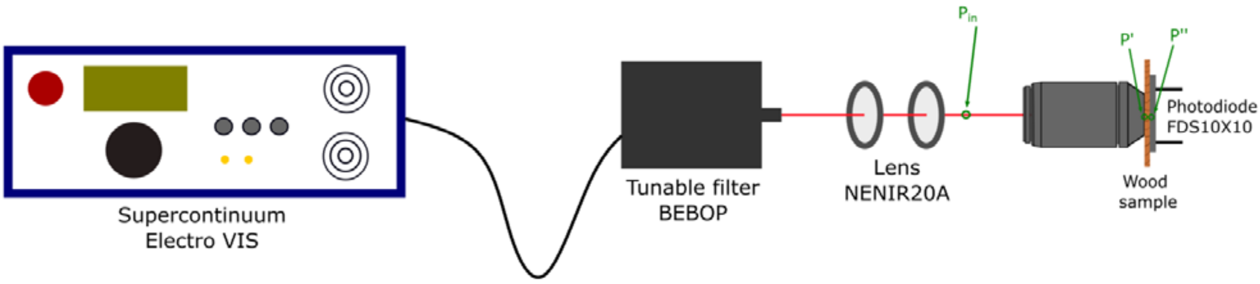

Fig. 3 – Experimental set-up for measuring the transmittance of wood samples

The light source is composed of a supercontinuum, which emits over a wide range of wavelengths, as well as a filter selecting a specific wavelength (from 350 nm to 800 nm) and a spectral bandwidth around it (from 5 to 100 nm wide).

The supercontinuum initially emits radiation at 1064nm, and then by non-linear effects covers a wide spectral band from 350 to 2350 nm. Nevertheless, the power at 1064nm remains much higher than at other wavelengths. Two NENIR20A filters were placed in front of the source output to reduce this effect.

The MPLFLN20x lens is used to focus the beam on the sample in order to obtain a spot surface as small as possible.

The photodiode, which is conversely polarized (Fig. 4), is pressed against the wood sample to maximize the received light. The output power is determined by measuring the voltage to the resistor terminals. The value of the resistor is adjusted so that the photodiode is never in a saturation state.

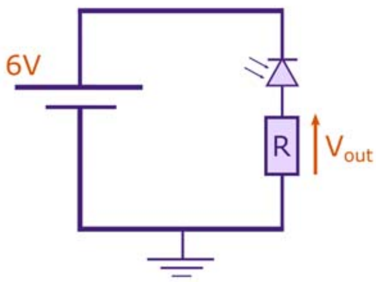

Fig. 4 – Electrical diagram of the photodiode polarization

Methods

The objective is to determine the transfer function of each wood sample, which is defined by:

$$Tr_{wood} = \frac{P''}{P'}$$

It depends on P' and P'', two intermediate powers that cannot be measured because the MPLFLN20x lens, the wood sample and the photodiode are pressed against each other.

The transfer function of the lens is defined by:

$$Tr_{lens} = \frac{P'}{P_{in}}$$

The transfer function of the photodiode is defined by:

$$Tr_{photodiode} = \frac{I_{out}}{P''}$$

In practice, for some wavelengths, the measured power will be too close to the surrounding noise. Instead, we will measure the voltage to the resistor terminals and the value of the resistor. The transfer function of the photodiode can therefore be noted:

$$Tr_{photodiode} = \frac{V_{out}}{P'' * R}$$

Finally, the transfer function of the wood sample is rewritten as follows:

$$Tr_{wood} = \frac{V_{out}}{Tr_{lens} * P_{in} * Tr_{photodiode} * R}$$

To use this formula, the transfer function of the lens and photodiode must first be determined.

These are determined as follows: For wavelengths ranging from 400 to 800 nm, with a step of 25 nm and a window of 10 nm, measurements of the power of the light beam are made before passing through the studied element and after passing through the element. The transfer function of the element is the ratio between the power at the output of the element and the power before passing through the element. Once these elements are determined, we can proceed to the power measurements on the wood samples.

In order to highlight differences or similarities caused by the orientations or species of the samples, it was chosen to measure the transmittance of the 8 samples of 1 mm thickness at a single point taken randomly on each sample.

A moving table on which the sample is placed is then added to the experimental set-up. This allows transmittance measurements of a grid of points on the surface of the sample. A 10 mm x 10 mm area with a resolution of 0.1 mm x 0.1 mm is scanned on each sample. Two pieces of tape that form an angle are placed on the sample, so that the image of the sample and the obtained transmittance map can be matched.

The results obtained for these two series of measurements are presented and discussed in the following section.

RESULTS AND DISCUSSION

The transmittance values in the case of the first measurement campaign (measure on a unique random point of the sample) with respect to the emitted wavelength is shown in Fig. 5. The first trends are:

- All 8 curves show the same general trend, i.e. a higher transmittance in the near infrared (800 nm) than in the near ultraviolet (400 nm).
- A slight difference in the shape of the curves is visible between poplar/Douglas fir and oak/beech. The transmittance of the first two species seems to start stabilising or at least growing more slowly around 800 nm while the transmittance of the other two species continues to grow. This may simply be a translation, but measurements beyond 800 nm are needed to confirm this.
- The transmittance in tangential section is higher than the transmittance in radial section for all 4 species.

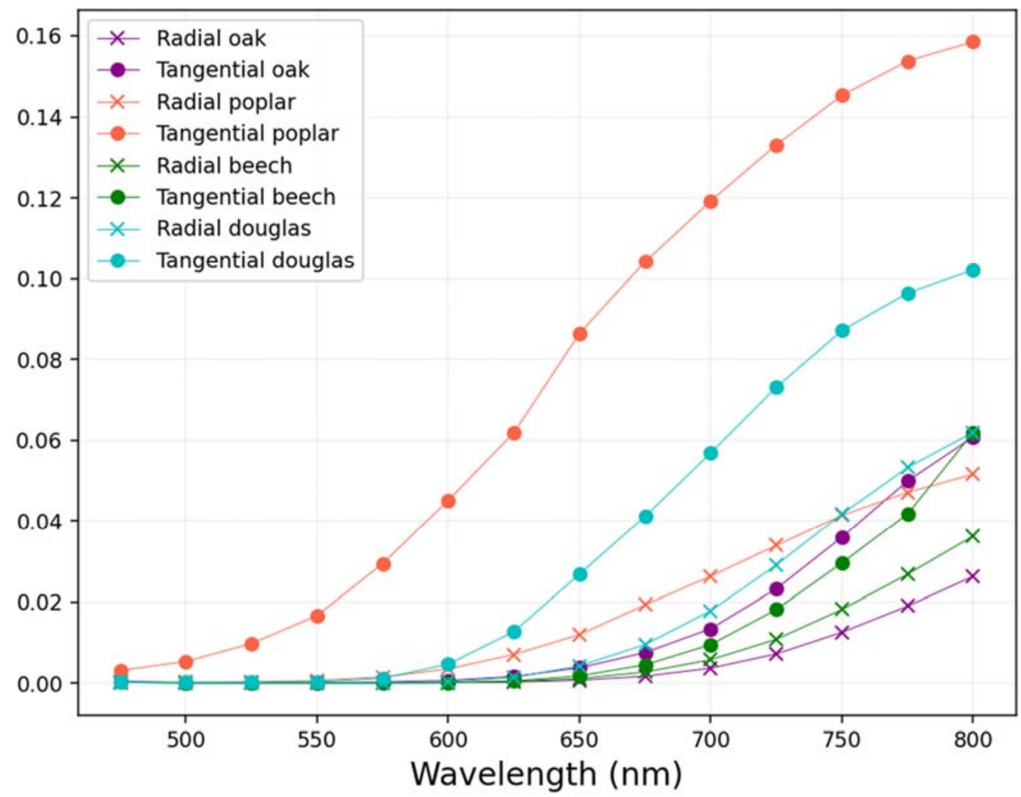

Fig. 5 – Transmittance of 1mm thick samples at a random point in each sample

The results obtained seem to show trends, but are not generalizable, as they are based on any one point in the sample. The same measurements are therefore being made on several points defined by a grid of the sample in order to obtain a transmittance map (Fig. 6).

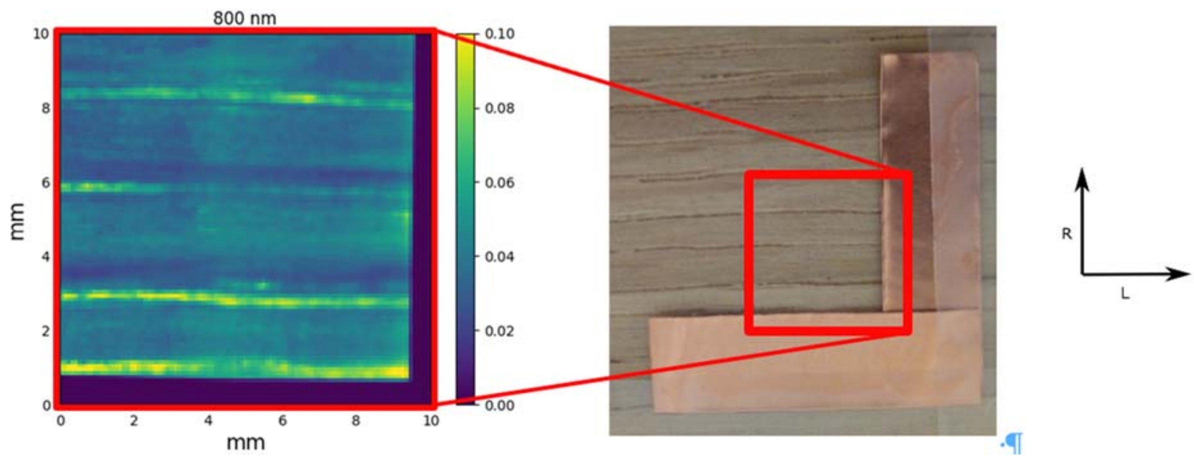

Fig. 6 – Transmittance map of the oak sample in radial section at 800 nm on the left and photograph of the scanned area in the red square on the right

The maps obtained allow to recognise patterns visible to the naked eye as wooden rays or color difference between earlywood and latewood.

The hypothesis of greater scattering in the near infrared than in the lower wavelengths is confirmed on the transmittance maps (example on Fig. 7) that we have made.

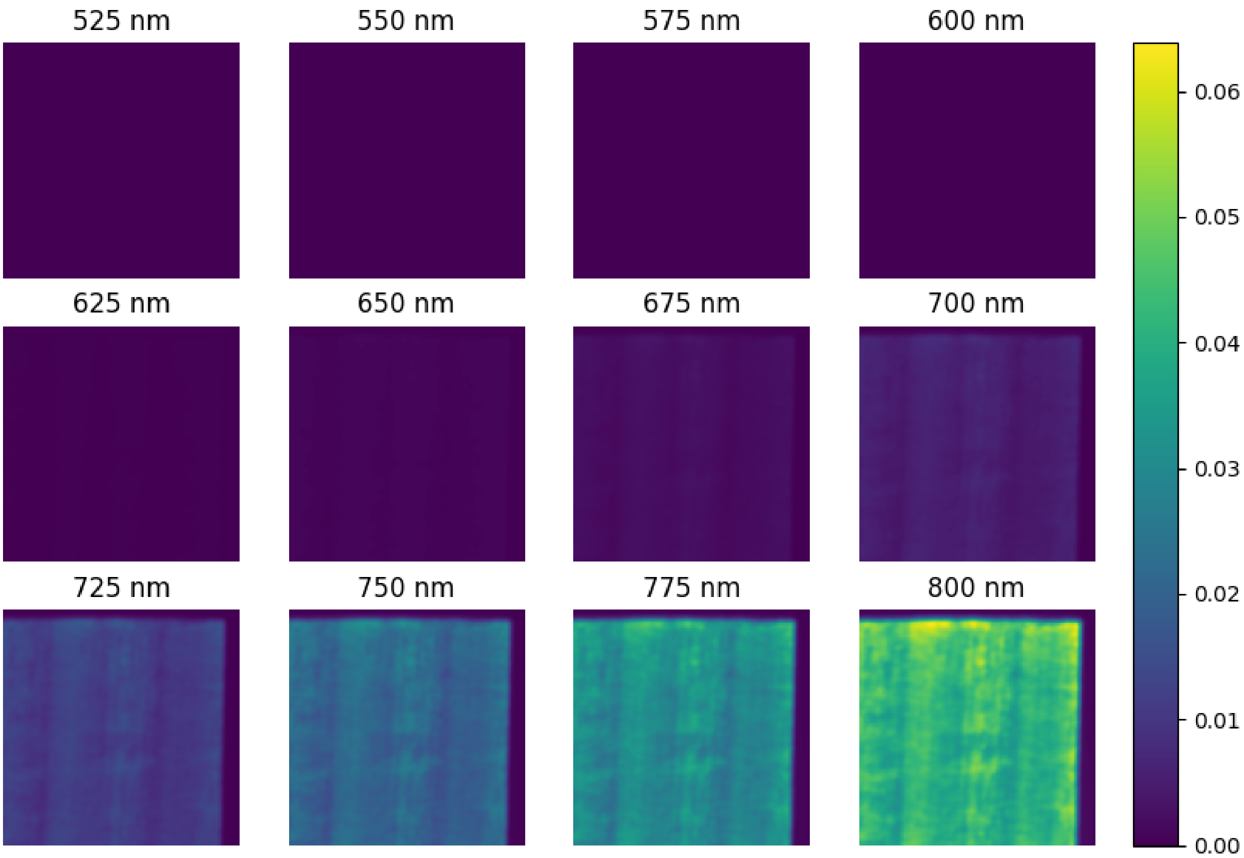

Fig. 7 – Transmittance of the 3 mm thick Douglas Fir sample at different wavelengths

However, better transmission does not necessarily mean better highliting on the specificities of the sample: Figure 8 shows two transmittance maps made on the same sample and on the same grid of points with two different wavelengths (600 and 800 nm). While the overall transmittance of the 800 nm map is higher than that of the 600 nm map, the latter highlights contrasts between the rings that are not visible on the other map.

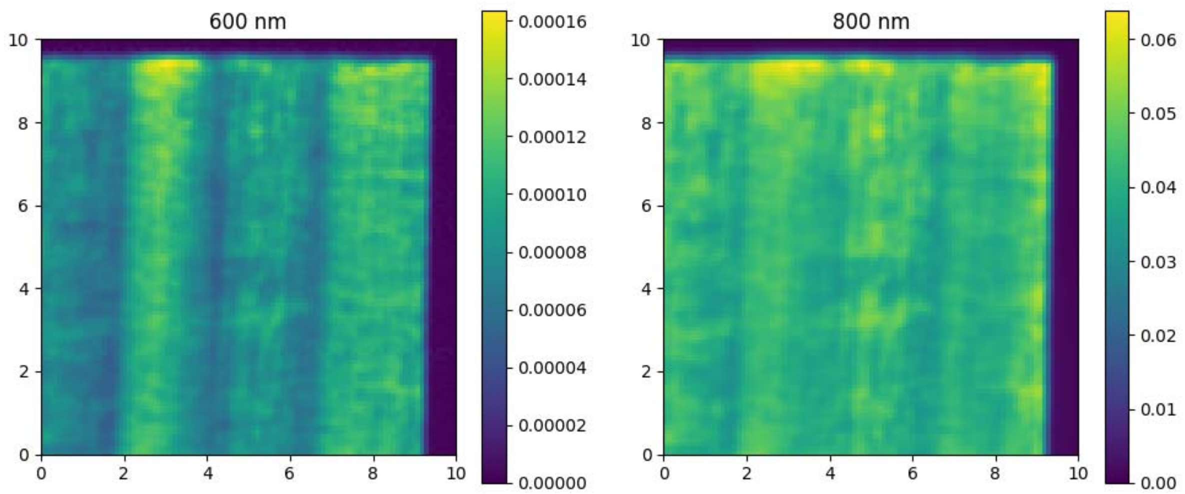

Fig. 8 – Transmittance maps with 600 nm light and 800 nm light

In the future, further measurements will be made using a rigid support instead of tape in order to improve the correspondence between the image and the mapping.
Work is also being done to increase the speed of mapping.
The next step in our experiments is to replace the photodiode with a lens and a camera so that we can work on images of ellipses and not only on transmittance values.
It is also planned to carry out light scattering simulations in simplified wood models in order to investigate the parameters that may influence the tracheid effect and to compare the results of these simulations with experimental data.

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