ASPEN
DECAY AND STAIN
MEASUREMENT

1995

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This is a joint publication of Canadian Forest Service and
Land and Forest Service pursuant to the
Canada-Alberta Partnership Agreement in Forestry

A6005-126

DISCLAIMER

The study on which this report is based was funded in part under the Canada-Alberta Partnership Agreement in Forestry.

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Catalogue No.: Fo42-91/126-1995E
ISBN: 0-662-23403-0

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ABSTRACT

As part of a co-ordinated program of research on fungal decay and stain on aspen, and its effect on aspen pulp production, the optical characteristics of sound and decayed aspen were measured.

Field samples were carefully selected and identified with decay from the *phellinas* and *penofira* fungi.

Two findings were made:

1. Near the decayed wood (in pockets) there is a luminescence which peaks at 560 nm and is observed under ultraviolet (UV) excitation.

2. The stained wood shows diminished (50%) reflectivity in 480 nm regions. This diminished reflectivity uniformly vamps upward so that by 1000 nm there is no difference between the reflectivity of clear fibre and of stained or decayed wood.

ACKNOWLEDGMENTS

Staff at VisionSmart wish to acknowledge the contributions of many people who have contributed to this work. First, the principal researchers, Dr. F. W. Weichman at the University of Alberta Department of Physics, and Dr. M. R. Cervenan of the Laser Institute; their respective associates including Z. Ge at the University of Alberta, and Dr. R. J. Willis, and Mr. R. Bonskowski at the Laser Institute.

Additionally, we would like to thank Gordon Sanders at Slave Lake Pulp and Gregg Neilson at Millar Western for taking the time to clarify mill requirements.

Finally, we would like to thank Russel Bohning and Dr. Yasu Hiratsuka at the Northern Forestry Centre of the Canadian Forest Service for their guidance and support, and the Canada-Alberta Partnership Agreement in Forestry, B.2 Sub-committee, for making this work possible.

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INTRODUCTION AND PROJECT BACKGROUND

In September of 1992, at a meeting chaired by Russel Bohning of The Northern Forestry Centre of the Canadian Forest Service, several diverse stakeholders interested in researching aspects of decay in aspen were brought together. Participants included representatives of Alberta aspen-based pulp mills, the Canadian Forest Service, the Alberta Land and Forest Services, most of the wood-based research institutes in Canada, and several research companies.

At that meeting three key points were made clear:

1. Decay in aspen and poplar was causing difficulty in the pulping process.

2. The principal difficulty lay in the darkening of the pulp, which was a direct consequence of dark or stained chips.

3. Most of the darkening of the wood fibre (which was ultimately chipped) originated in the many fungal decays which attack living aspen and poplar, and felled stems.

A variety of approaches to attack this problem were put forward.

One obvious approach identified was to use computer processing of optical scanning of stems or chips to identify stained or decayed fibre before it entered the pulping process.

Unfortunately, as pointed out at that meeting, nothing scientific was known about the optical characteristics of sound and decayed aspen wood.

PROJECT GOALS AND PROCEDURES

The primary goal of the research presented here was to identify the best practical scanning approach which will reliably detect fungal decay and stain. This work leads directly to the capability to measure the brightness of chips to help control the pulping process.

The project proceeded as follows:

1. Samples were collected in the field of aspen infested with a variety of fungal decays as identified by the handbook, A field guide for classification and measurement of aspen decay and stain, based on Dr. Yasu Hiratsuka's work.

2. The specimens were brought to the Northern Forestry Centre, and the fungi cultured for exact identification.

3. Samples numbered W1 through W10 were cut from the stems and distributed to both the University of Alberta and the Laser Institute.

4. Work at the Laser Institute focused on a dramatic effect first observed jointly by VisionSmart, the Laser Institute, and the Canadian Forest Service - the ultraviolet (UV) induced fluorescence of decayed aspen wood samples.

5. Work at the university was more broadly based, looking at the general reflection characteristics of the wood, while at the same time keeping track of general UV induced fluorescence.

6. The mill participants - Millar Western Pulp Ltd. and Slave Lake Pulp - were visited to clarify how the research could best be applied.

The data collected in this study are presented in this overall report, along with conclusions and recommendations. The technical details are spelled out in the two sections which follow.

SUMMARY RESULTS

Two separate findings resulted from the research conducted on this project:

1. At room temperature, a yellow-green luminescence appears in aspen samples in a pattern which seems to be associated with growth or decay. This luminescence arises when the aspen samples are illuminated by UV light, and may hold new scientific clues to how growth and decay function in aspen. This yellow-green luminescence is in contrast to a blue luminescence which seems to be found in the clear unaffected wood fibres.

   The yellow-green and blue luminescence were present in all the samples collected and were of a broad spectral character (no sharp peaks). When present, the yellow-green luminescence appears to be brighter.

   Preliminary work carried out at the university suggests that the colour of the luminescent emission may shift with temperature, becoming more blue and much brighter as the temperature moves toward -180°C.

   This is an exciting new piece of science and bears further investigation.

2. The reflectivity curves associated with clear fibre and stained fibre are all smooth. The stained fibre found in the samples examined (containing *phellinas* and *penofira* fungi) is strongly deficient in the blue end of the spectrum, but shows no appreciable difference in near infrared (IR) reflectivity.

This clearly marked tendency should make it possible to develop prototype instrumentation to measure and quantify the percentage of stained chips moving on a belt.

LUMINESCENCE

Introduction

With the recent expansion of Alberta's pulp and paper industry, aspen and balsam poplar are increasing in commercial importance. However, in comparison with other feedstock species, the quality of aspen and balsam poplar is highly variable. This impacts the quality of pulp produced and the degree of processing required to produce pulp of a specific grade.

The results discussed in this report suggest that laser induced fluorescence is potentially useful for aspen grading. When the ten aspen samples, provided by the Canadian Forest Service, were irradiated with UV light from a nitrogen laser (337 nm), visible distinctions between the healthy aspen and affected aspen were readily apparent.

The spectrograph signal of healthy aspen wood is centered at approximately 455 nm (blue), and shows no fine structures within the peak. The area of yellow fluorescence, found along the border between decayed and healthy wood, consists of two distinct peaks. The first corresponds to the signal of healthy aspen wood. The second, characteristic of aspen decay was centered at approximately 540 nm (green-yellow) and had a similar shape to that of the first signal. Again, there are no obvious fine structures in this broadband signal. The Laser Institute's hypothesis that the dual peak signal observed with the affected aspen is a convolution of two distinct signals, is well supported by excellent curve fits using gaussian exponential mathematical fitting equations.

A single wavelength (337 nm) excitation source was used in the work performed for this initial study. However, it was noted that different areas of fluorescence were observed when examining the cross sections under a black light containing several lines of excitation. This suggests that the process is wavelength dependent. Tuning the laser while examining the spectrum of the fluorescence is likely to reveal additional information, which could be useful for identification of different types of decay or stain.

In the present study, The Laser Institute has succeeded in distinguishing between healthy and affected aspen. More work is required to determine to what extent it is possible to distinguish between different types of decays or stains. The samples used for this study had only two very similar types of fungi. Future work is recommended to characterize variations that may exist between different types of decays and stains, especially in the blue stain and to investigate effect of excitation wavelength on the fluorescence signature of the decay.

The work described in this section is an introductory study to observe and record the fluorescence emitted from aspen tree trunk cross-sections when illuminated with UV light. Ten aspen cross-sections with similar decays were analyzed. The fluorescence study was carried out using a nitrogen pulsed laser as the excitation source and a spectrograph as analyzing tool.

Three areas of the wood can be identified. The area where no visible decay is obvious will be called healthy wood. Between the healthy wood and the area of obvious decay, there is a region which has a yellow fluorescence when irradiated with UV light. Often this region is not easily differentiable from the healthy aspen wood under normal light conditions. This area is designated

as affected decayed wood; possibly active growth of the fungus. As a last region, the visually rotted area is designated decayed wood. Each of these areas on each cross section were irradiated.

System Design

The system was designed to favorably couple light from the fluorescing area of the cross-section into the spectrograph. The excitation source was a high power LN1000 N2 laser (337 nm, 2 MW peak power, 600 pulse width) manufactured by Laser Photonics. The UV laser radiation was coupled through an optical fiber (25% transmission) that allowed us to easily direct the laser at the sample without the need for further beam optics.

The wood samples were mounted on a movable stage behind a sheet metal mask which was painted flat black. A 3 mm hole in the mask defined the area on the wood sample that was flooded with the laser light. By moving the sample of wood it was possible to quickly collect light from any region of interest. The mask was required to eliminate any possible interference of signals from different regions of the cross-section.

The collection optics were designed to collect light from the unmasked area. The collected light was collimated and then focused on the spectrograph slit, thereby matching the f/# of the spectrograph. To prevent 337 nm radiation of the laser from entering the spectrograph, a high pass filter (GG395) blocking radiation below 395 nm was placed in front of the spectrograph slit.

The spectrograph is a 0.5 m focal length, triple grating instrument manufactured by Acton Research Corporation. Data collected for this study used the 150 groove / mm grating with a 500 mm blaze angle. The signal was recorded with an intensified 700 element detector, giving a resolution of approximately 1 nm.

The system was assembled on an optical breadboard. After optimization, the setup remained undisturbed for the duration of this experiment. The schematic of the setup is illustrated in Figure 1.

Results

A trial run with Sample 2 shows the relation between healthy wood, affected wood, and the reflectance standard (Figure 2). The blue colour of the illuminated wood is confirmed by the peak at about 440 nm, and the yellow glow is seen in the peak at 560 nm. The fluorescence observed is broadband; no narrow spectral features were observed.

The affected wood is usually near decay regions, but does not correspond directly to stained or clear fibre.

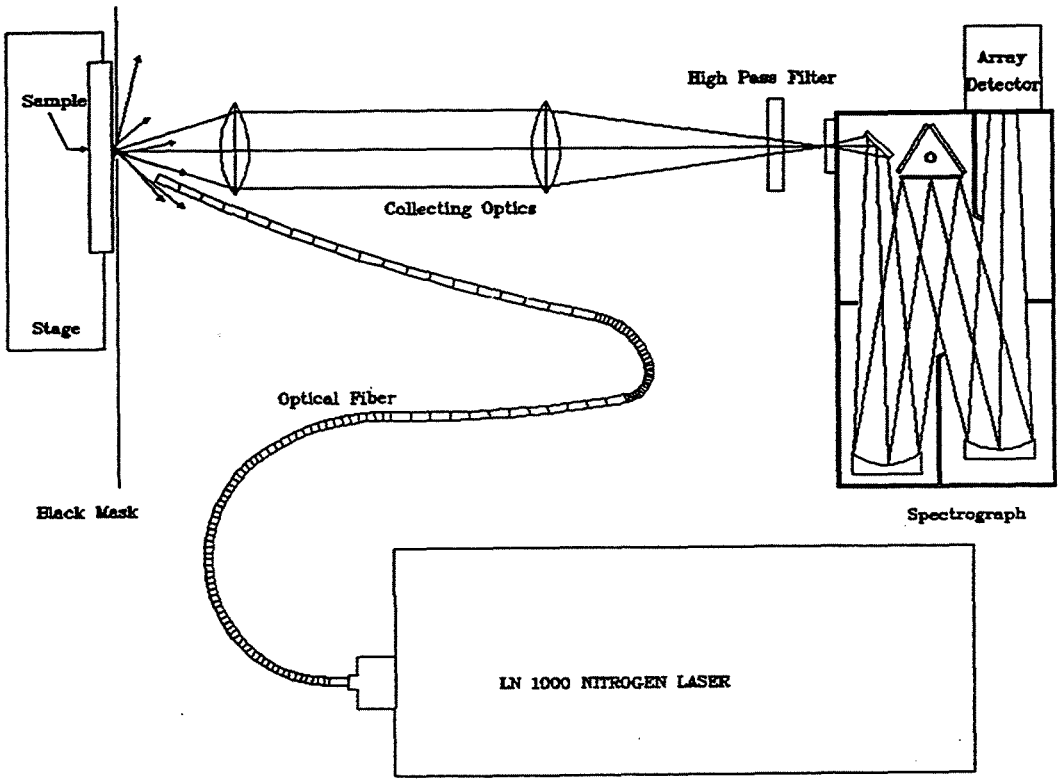

Figure 1. Schematic of system setup.

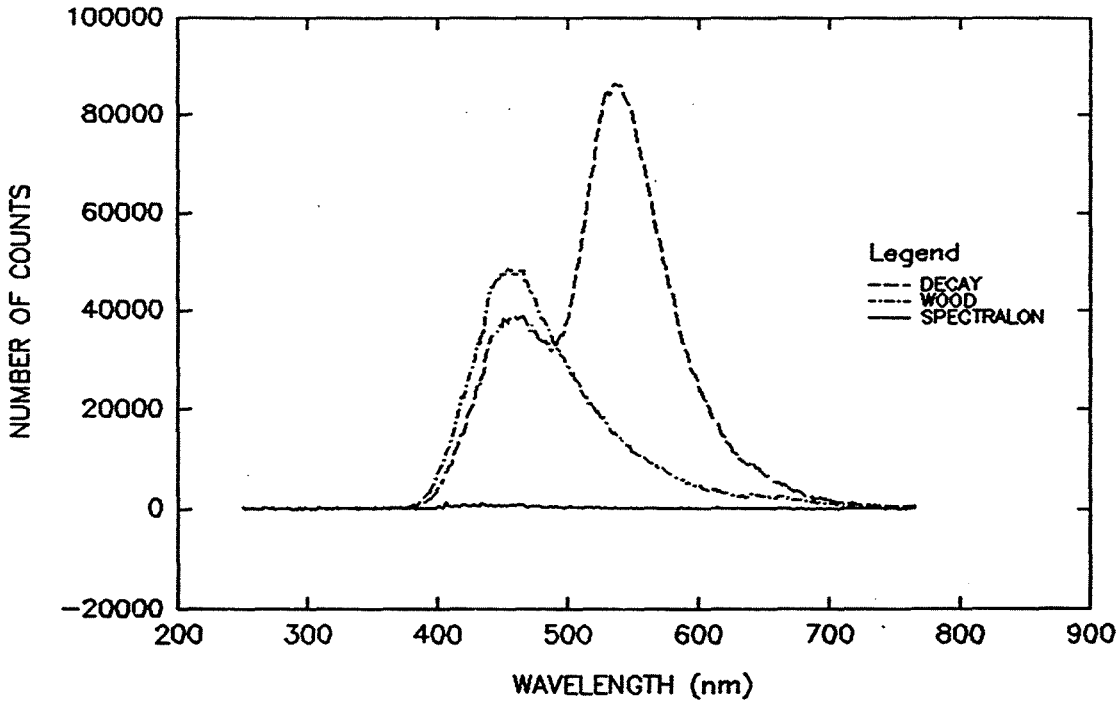

Figure 2. Comparison of the fluorescence of healthy wood, affected wood, and the reflectance standard (spectralon).

REFLECTIVITY

Introduction

A series of laboratory measurements of reflectivity were made in clear, stained, and unsound specimens to see what easily recognizable differences exist that could enable the pulp industry to install automated recognition systems.

To distinguish various stains from unblemished wood, we made diffuse reflection measurements to find those wavelength regions where the differences were greatest.

The laboratory reflection measurements were made on small samples of wood cut from larger sections taken from aspen stems. Dr. Yasu Hiratsuka's laboratory made ten specimens available to us.

These specimens had been tentatively identified for type of fungal infestation following the handbook developed by Dr. Yasu Hiratsuka et al. Subsequently the specimens had been brought to the Northern Forestry Centre, and the fungi cultured for exact identification.

Samples numbered W1 through W10 were cut from the stems. For more detailed information, and a complete set of photographs, contact VisionSmart Inc.

Repeated measurements were made on each sample and more than one sample of each type of blemished and unblemished wood were investigated.

Instrumentation

No attempt was made to obtain absolute diffuse reflectance since this would be too difficult to obtain in the field.

Since our primary aim was to distinguish between sound and stained chips, we made relative reflectivity measurements from the near UV at 340 nm to the near IR at 1040 nm.

Magnesium oxide powder often used as a standard has proven to be too easily destroyed in handling while changing wood specimens.

A flat piece of white Coors porcelain, from a crucible cover, proved to be ideal after the glazing had been ground off. The reflectivity of the porcelain ranges between 60-85% over the spectral range of interest as compared to freshly prepared magnesium oxide.

Note that because of the relative nature of the measurements, a reflection coefficient of greater than 1.0 presents no difficulties.

The basic setup consisted of a monochromatic (or single coloured) light source that was alternatively used to illuminate a reference sample (taken from clear fibre) and the comparison sample under test.

A sensitive detector was then used to compare the reflectivity of each of the two sources and the ratio taken.

A dc-powered 100-W 12-V quartz halogen light source (Philips 12507) was focused through a mechanical chopper operating a 15 Hz on the entrance slit of a Kipp and Zonen double prism monochromator with flint glass prisms. The monochromatic light from the exit slit was allowed to fall on a sample holder 3.5 cm away and inclined to the optical axis by 30°. The detector (RCA 7120 photomultiplier) was mounted at right angles to the beam emerging from the exit slit, thus giving an angle of incidence of 30° and an angle of reflection of 60° avoiding specular reflection angles by a good margin. No lenses or mirrors were used between exit slit and detector. The signal from the photomultiplier was measured with a lock-in amplifier (Ithaco Dynatrac 391 A) tuned to the chopper frequency.

The sample holder was a slider of aluminum with two identical round holes, 13 mm in diameter, large enough not to block any of the light from the exit slit. The wood sample was mounted against and behind one hole; the reference was mounted behind the other hole. The slider was constrained to move between accurately placed stops, allowing rapid and reproducible reflectivity comparisons to be made. The entire exit slit to PMT assembly was made light tight against extraneous radiation.

The monochromator had been calibrated against mercury, argon, thallium, krypton, and other spectral sources.

Samples were cut from blemished or healthy wood to a size of 2 cm x 2 cm x 1 cm. The sample was attached to the slider with contact cement on the edges of the sawn face. As a precaution against light leakage, thick black paint was applied along the edges where the sample was stuck to the slider.

Results

Sample W4 was identified as having the clearest fibre. Consequently it was selected as the standard sample.

The relative reflectivity of this clear fibre was compared against white porcelain. The results obtained are similar to those for softwoods.

Care was taken to insure that the wood did not discolour over time, since the measurements took place over a five month period. Measured variations did not exceed 2%.

One unusual effect observed was that sanding the aspen could change reflectivity by as much as 40% in the 400 nm region. Fortunately this type of surfacing does not occur in industry.

Figure 3 shows the relative reflectivities of a stained sample. As is evident, the brown stain common in aspen has a smooth spectrum, with a marked deficiency of reflection at about 480 nm. As is also evident, the reflectivity of both the brown and clear fibre is unchanged at about 1000 nm.

Before the samples were selected each stem was irradiated with UV and the location of yellow-green luminescence noted.

The presence or absence of luminescence seemed to have no effect on the reflectivity.

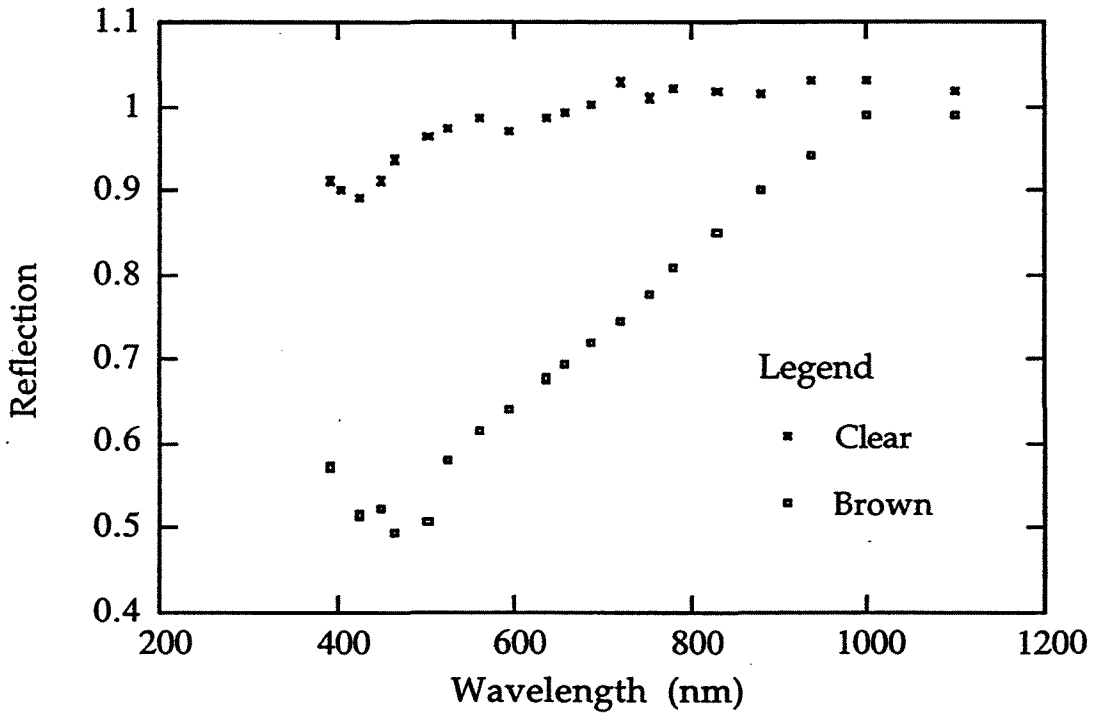

Figure 3. Reflection spectra from clear and decayed fibre.

OVERALL CONCLUSIONS AND RECOMMENDATIONS

Discussions with the mill participants clearly indicated the following interests:

1. It would be desirable to develop instrumentation which would allow for the quantification of the percentage of dark chips present leaving the chipper, or entering the plant. These chip streams generally are transported by belts approximately 1 m wide moving at approximately 6 m/sec.

2. It may be desirable to sort chips using this instrumentation as it leaves the chipper, so that (for example) chips with more than 85% brights are piled in one pile, and those with less than 85% are separated for ad-mixing into lower grade pulp products.

3. It may be desirable to position this instrumentation in advance of the infeed to the pulping process to provide feed forward compensation of bleaching and process time requirements to achieve optimum efficiency in achieving adequate pulp brightness.

The reflectivity results obtained suggest that a two camera system, operating with filters in the near IR, and the deep blue, could provide meaningful indications of the percentage of stained chips on a transport conveyor. The development and testing of such an instrument would seem an obvious next stage to the practical research.

On the scientific side, it seems clear that the luminescence results discovered and presented here may provide new insights into some of the bio-chemical mechanisms at work in aspen and aspen decay.