IMPLEMENTATION OF OPTICAL MEANDERS IN THE TEMPERATURE MEASUREMENT OF THE EXTERMINATION OF BASIDIOMYCETE SERPULA LACRYMANS USING MICROWAVE HEATING

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Abstract. *The dry rot basidiomycete Serpula lacrymans is the most common and destructive wood decay fungus, which attacks and damages houses and other wooden construction worldwide [1], [2]. Effective chemicals have been developed for remediation and treatment of dry rot outbreaks and for wood preservation against dry rot, but in most cases, control is most economically achieved by environmental management to avoid creating favourable growth conditions for the fungus [3]. Thermal treatment using microwaves represents one of possible approaches in fungal growth control and refurbishment of damaged wooden constructions. One of the possibilities, how to monitor this whole process seems to be the use of Optical fiber DTS (Distribution Temperature Systems). The Optical fiber DTS are unique distributed temperature systems using optical fiber as a sensor. Due to the electromagnetic resistance is this system suitable for the monitoring of these processes. This article deals with application of optical meanders in the temperature measurement during the extermination of basidiomycete Serpula lacrymans using microwave heating. Because of the adverse effect of microwave radiation on all other types of temperature sensors.*

Keywords

Microwave emitter, microwave heating, optical fiber DTS, optical meander, Serpula Lacrymans.

1. Introduction

The Optical Fiber DTS (Distributed Temperature System) are unique distributed temperature systems using optical fiber as a sensor. Temperature values are recorded along the optical fiber continuously in points. DTS system can be imagined as several thousand sensors providing information on the thermal state of the environment in which the optical fiber is located. These systems are mainly due to their advantages, utilized in many applications [4], [5]. The biggest advantages are:

- resistance to electromagnetic radiation,
- resistant to aggressive environments,
- the length of the measured section up to the 30 km.

As the name suggests, Optical Fiber DTS based on Stimulated Raman Scattering are using nonlinear Raman scattering. Lasers used in these systems operates at a wavelength of the 1064 nm. Raman spectra peaks are in this case shifted by ±40 nm. That is equal to 1104 nm and 1024 nm. These two newly incurred components that arise from the reflections on the core and cladding boundary along the optical fiber are two parts of the spectrum and named as Stokes and Anti-Stokes component. Exactly the Anti-Stokes spectra component changes its intensity depending on the temperature along the fiber. The Stokes part of the spectrum is thermally independent. The DTS defines the location of temperature based on changes in the intensity of the

Anti-Stokes spectrum and final ratio between Stokes spectrum [6]. Spatial resolution of the DTS system is standardly about 1 m with accuracy of ±1 °C, at a resolution of 0,01 °C.

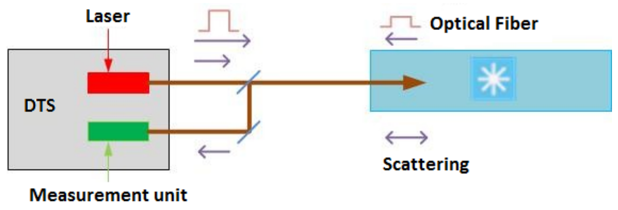


Fig. 1: Block diagram of the DTS system.

Spatial information about the temperature distribution along the optical fiber is achieved using a technique called Optical Time Domain Reflectometry (OTDR) which is nowadays mostly used for optical testing line [7] (seen in Fig. 1).

2. Optical Meanders in Point Mode

If it is necessary to ensure accurate localization in the measurement process, it is appropriate to apply optical meanders in the point mode. Point mode means that some point is created sensoric ring of optical fiber. In practice, it is often required the sensoric ring to have the smallest sizes (inner diameter and length of the optical fiber in the ring). It is obvious that the dimensions of the sensoric ring will vary with different parameters of optical fibers.

In the case of use multimode optical fiber with only primary protection (outer diameter 250 µm) decreases the critical inner diameter of sensoric ring to value 3 cm. The curve shows the different inner diameters of optical meander. If the inner diameter reduced below the 3 cm then created too large attenuation. This method will be inaccurate. Shown in Fig. 2.

According to another experimental measurement the length of multimode optical fiber in the sensoric ring has a critical value of 3 m [9].

3. Measurement of Microwave Emitter's Mean Power

This measurement was performed in the Department of Theoretical and Experimental Electrical Engineering laboratory. For measurements was used the microwave emitter with a magnetron type NL 10250. This emitter operates at the frequency of 2,45 GHz and at the wavelength of the EM wave 12,25 cm. The

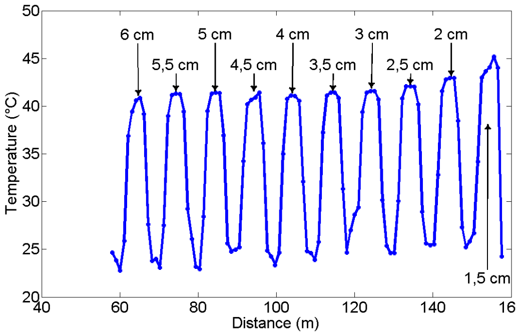
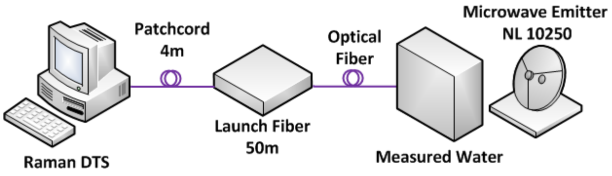


Fig. 2: Effect of the inner diameter of the sensoric ring on the measured temperature of the water bath (measured together, optical fiber with primary protection, inner diameter 250 µm), [8].

listed maximum power is 1,9 kW. Antenna for directing the flow of energy has a funnel shape with an aperture of 270 × 270 mm. A calorimetric method was chosen for the actual measurement of microwave emitter's mean power. Water was placed into the rectangular tank containing 10 litres. Time of microwave emitter radiation heating of the container with water was set to the 10 minutes. Temperature changes during the time of the experiment were measured by using DTS (Distributed Temperature System) and for larger precision of the measurement were used optical meanders. Scheme of measurement is shown in Fig. 3(a) and the process is shown in Fig. 3(b).



(a) Scheme.

(b) Process.

Fig. 3: Scheme and process of measurement microwave emitter's mean power.

Optical meander was immersed directly into the water in the container. Measurement was performed for two limit values of microwave emitters. At first the minimal power of microwave emitter P_{min} was set and then was set the maximal power P_{max}. From the default calorimetric equation:

$$Q = m \cdot c \cdot \Delta t = W = P \cdot t_c, \tag{1}$$

was expressed the measured power of the microwave emitter and the value P_{min} was calculated, whose temperature process is shown in the Fig. 4. The starting water temperature was 15,6 °C and during the 10 min. heating was water warmed to 24,5 °C:

$$P_{min} = \frac{m \cdot c \cdot \Delta t}{t_c} = \frac{10 \cdot 4180 \cdot 15,4}{600} = 620\ [W]. \tag{2}$$

After calculating the P_{min} value the power of microwave emitter was changed to the maximum value and then was the value P_{max} calculated, its temperature course is shown in Fig. 5. The starting water temperature was 22,5 °C and during the 10 minutes heating was water warmed to 37,9 °C:

$$P_{max} = \frac{m \cdot c \cdot \Delta t}{t_c} = \frac{10 \cdot 4180 \cdot 8,9}{600} = 1073\ [W]. \tag{3}$$

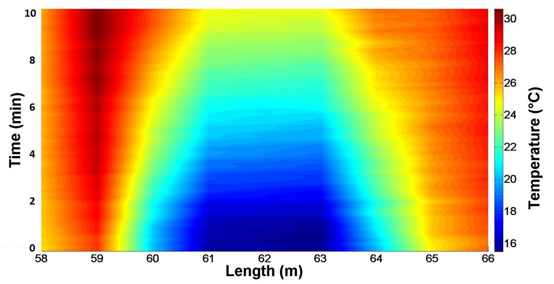


Fig. 4: The temperature measurement for P_{min}. X-axis represents the total length of fiber, which is zooming in to the measured optical meander. Measured optical meander is located in the section between 60,5 m to 63,5 m.

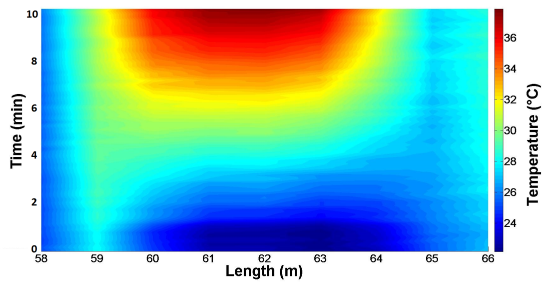


Fig. 5: The temperature measurement for P_{max}. X-axis represents the total length of fiber, which is zooming in to the measured optical meander. Measured optical meander is located in the section between 60 m to 63 m.

Due to the easier calculation and better understanding of the temperature values were the values of the initial and final temperature of the water substituted in °C. The final values of the temperature differences are exactly the same as in the case of substituting values in Kelvin [10], [11].

4. Extermination of Serpula Lacrymans Using Microwave Heating

Oat flakes were mixed with water (6:4 W/W) and autoclaved. Bricks (10 × 10 × 1, 5 cm) were prepared from the material in plastic bags in aluminium form and autoclaved again after 3 days. Bricks were then inoculated with agar plugs from ME agar on Petri dishes (malt extract 7 g/l, agar 20 g/l, pH 7,0) with S. lacrymans (CCBAS110) and cultivated at 25 °C in darkness for 14 days. After microwave heating, samples from all bags were taken and ME agars were reinoculated. Mycelial growth was checked daily during the next 10 days.

Fig. 6: The temperature measurement for one optical meander.

The measurement was carried out in the Department of Theoretical and Experimental Electrical Engineering laboratory again. In each measurement were used two samples and between these two samples was placed meander composed of measuring optical fiber (Fig. 6). The aim of this measurement was to determine the required time for the operation of the microwave emitter for the consumption of dry-rot fungus. The temperature of the sample had to be maintained over 90 °C, because this is the temperature limit for destruction of the tested Serpula Lacrymans. However, the temperature could not significantly exceed the value of 100 °C, because the measured sample could ignite. The microwave emitter was operating in the sample's temperature range between 90 to 100 °C so that was switched off at 100 °C and switched on if the sample's temperature dropped at 90 °C as can be seen in graphs.

The time intervals were chosen at 5, 15, 30, 120 and 240 minutes. This means that the sample had to be exposed to temperatures over 90 °C during this time intervals.

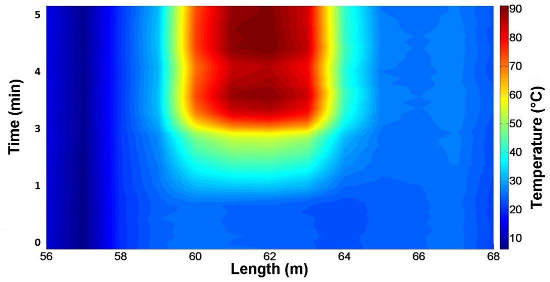


Fig. 7: The temperature measurement for one optical meander for a 5 min. X-axis represents the total length of fiber, which is zooming in to the measured optical meander. Measured optical meander is located in the section between 60 m to 63 m.

Measurements were divided into two parts. In the first part were first three time intervals (5, 15 and 30 min.) measured and in each time interval was used only one sample. The time course of the first measurement, 5 min. time interval is shown in Fig. 7.

After 5 minutes, the samples were changed and measurement in 15 min. time interval was initiated. The time course of this measurement is shown in Fig. 8.

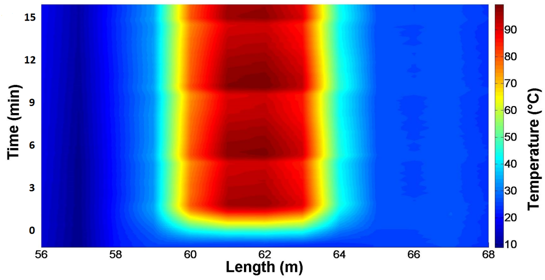


Fig. 8: The temperature measurement for one optical meander for a 15 min. X-axis represents the total length of fiber, which is zooming in to the measured optical meander. Measured optical meander is located in the section between 60 m to 63 m.

After 15 min. were the samples changed again the measurement in 30 min. was initiated. The time course of this measurement is shown in Fig. 9.

Due to the time demands were the last two measurements (120 and 240 min. time intervals) merged. In this measurement were used two optical meanders. Samples were placed one after another and heated together (Fig. 10). During measurement the first tested sample has been losing its original shape and was then less heated. Therefore, the operation of microwave emitter had to be longer. However, the second sample was heated much more. The temperature of the second sample was reaching the values up to 115 °C and the sample had to be constantly monitored. After 120 min. was one sample taken and measurement continued with only the second sample (Fig. 11).

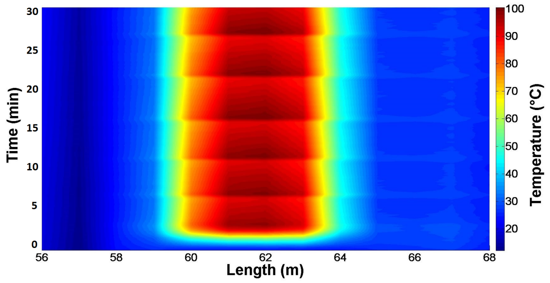


Fig. 9: The temperature measurement for one optical meander for a 30 min. X-axis represents the total length of fiber, which is zooming in to the measured optical meander. Measured optical meander is located in the section between 60 m to 63 m.

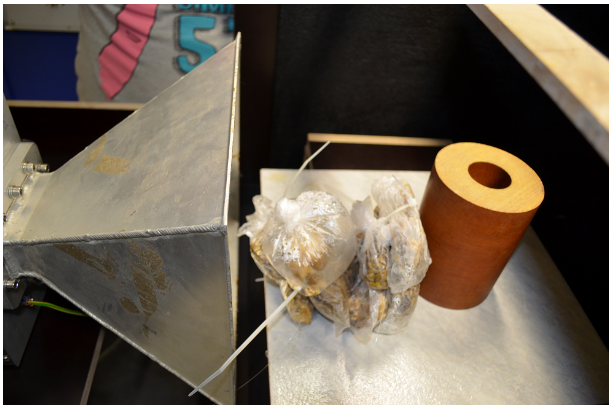


Fig. 10: The temperature measurement for two optical meanders.

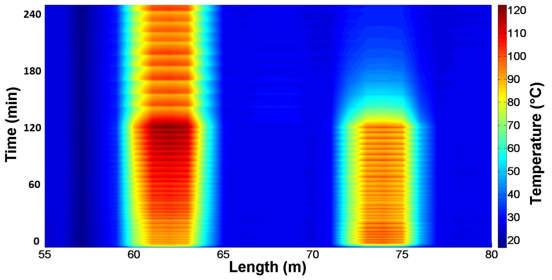


Fig. 11: The temperature measurement for two meanders. X-axis represents the total length of fiber, which is zooming in to the measured optical meanders. Measured optical meanders are located in the section: first between 71,5 m to 74,5 m and second between 60 m to 63 m.

After the measurement were the samples received by the researchers after from The Institute of Microbiology, on the Academy of Sciences of the Czech Republic (ASCR), v.v.i., for the next research and measurements, which had to confirm or contradict the extermination of the Serpula Lacrymans in the different time interval measurements.

The effect of high temperature on the fungal viability was tested by re-inoculation of treated samples on agar plates. No growth of the fungus was observed even after 5 min of microwave treatment. The experiments described here demonstrated the ability of microwaves to kill mycelial cultures of Serpula Lacrymans efficiently. However, the results obtained with oat flakes can not be generalized and applied to other materials such is wood or timber.

5. Conclusion

The aim of these measurements was to determine the functionality of using optical meanders to monitoring the temperature inside the tested samples during extermination of Serpula Lacrymans with microwave radiation. After successfully completing these experiments was ascertained the unique and reliable utilization of optical meanders and DTS in processes of extermination of Serpula Lacrymans by use of microwave radiation and that because of measured high accuracy of temperature and resistance to electromagnetic radiation. Given the current range of materials used in the sensors this method appears as the most reliable and most accurate.

Additional measurements and applications that we can use DTS resistance consisting in the application of optical meanders on a wooden beam. These beams will be heated up in two ways. In the first case it will be heated by hot air in the reconstruction process of old buildings. In the second case it will be heated by microwave emitter in the reconstruction process of old beams in laboratory. Our research team also done another measurements such as in terrain and the also at the research workplace in Zvolen.

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Jiri GABRIEL was born in Liberec, the Czech Republic, in 1963. Graduated in analytical chemistry (Faculty of Science, Charles University, Prague, 1987), Ph.D. studies in the field of fungal physiology (Institute of Microbiology, Czechoslovak Academy of

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