TIME RESOLVED PHOTOLUMINESCENCE MEASUREMENT USING DIGITAL OSCILLOSCOPE

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Abstract: A Time Resolved Photoluminescence measurement method using a digital oscilloscope is described in the range from the nanosecond to the millisecond region. The data can be greatly simplified by averaging the signals measured by the oscilloscope, and transferred to a computer. This method was applied for ZnO powder and is applicable in other fields.

1. Introduction

Time Resolved Photoluminescence (TRPL) measurement using digital oscilloscope was developed by T. Stacewicz since 1997 [1], and several authors [2, 3, 4, 5, 6] used and developed to measure TRPL spectra with the resolution of the order of nanosecond. Some advantages of this method are very high speed, high resolution and real time. This article proposes a simple setup but useful system for TRPL measurements.

2. Experiment

Figure 1 shows the TRPL measurement system. Pulse nitrogen laser was used. Iris and separating diaphragms were used for measurement of TRPL spectra depending on the intensity of the excitation light. Before hitting on photomultiplier tube (PMT) cathode, the emission photons from sample passes through the monochromator (education product) with both entrance and exit slits being of 0.05-0.1 mm in width. The photons of photoluminescence is detected by PMT R4457 [Hamamatsu] with a rise time at 1.5 ns and electron transition time at 15 ns [8]. In order to protect the PMT against stray light from the laser, a high pass filter with a cut-off at 370 nm [Jobin Yvon] was fixed in front of the monochromator. The output of PMT was connected directly to channel CH1 of TDS 3052B oscilloscope via a short coaxial cable. The laser beam from nitrogen laser source is split up by a beam splitter, a small part is reflected to the high speed Si-photodiode, this signal is used as trigger for data acquisition. Following each trigger a signal waveform was recorded and averaged after 128 samples before being transferred via LAN to the computer. The Wave Star Control Version

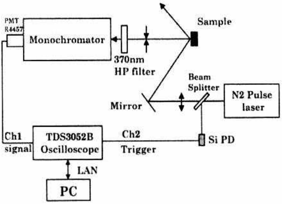
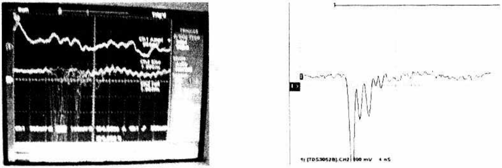


Fig.1. The TRPL measurement

2.0 [Tektronic] software recorded online. The data can be stored and analyzed offline to obtain TRPL spectra.

3. Results and Discussions

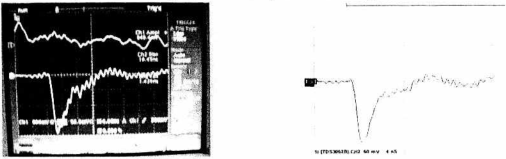
A typical photoluminescence decay curve is shown in Fig 2a, the trace in the upper screen is the trigger signal detected by the Si-photodiode. Trigger voltage is 192 mV. It means, whenever the rise voltage in CH2 channel reaches to 192 mV, the CH1 channel starts to collect data.



a) Oscilloscope b) Computer

Fig.2. Typical Photoluminescence decay curve with photon counting, each invert peak is corresponding to photons coming in the same time

After 128 samples were averaged, the PL decay is shown in Fig 3.



a) Oscilloscope b) Computer

Fig.3. Typical Photoluminescence decay curve after averaging 128 times.

To verify the accuracy degree of the obtained information, the system response time was measured and corrected. The key ideas of impedance matching adapted from the design ensure that the fast electronic signal propagates into the coaxial cable with no noticeable reflection (ringing phenomenon) [7, 9]. Figure 4 show the output signal when photons scattered from surface of sample arrives at the detector in the same time. The signal has a rise time of less than 1.5 ns, which is equal to PMT rise time and a FWHM about 2 ns. It is very important that there is no signal reflection or "ringing" after the main peak for high counting rate photon detection. Actually, there is a 2-3 ns time delay between this peak and the real start time, due to the propagation of the light from the sample to the detector. The curve form trigger T to the fall time point of invert peak is a part of electron transit time of PMT about 15 ns [8].

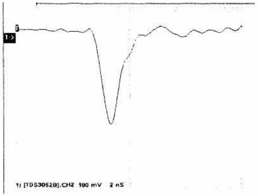


Fig.4. System response time measured by light scattered.

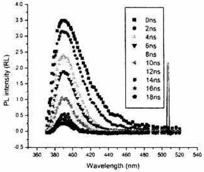


Fig.5. TRPL spectra of ZnO powder

The affection of error such as color effect is the dependence of time response of a PMT on wavelength. This dependence is thought to result from the wavelength dependence of the energies of the electrons ejected from the photocathode [7, 10]. In our system, the time error of color effect is smaller than the system response time. After photoluminescence decay data are recorded, the Origin software (Version 5.0 or higher) is used to analyzed for fitting and drawing the TRPL spectra. Figure 5 shows, for example, the results of some measurements and data analyzing.

4. Conclusions

The Time Resolved Photoluminescence measurement by pulse method using digital oscilloscope was built in our lab. The resolution time of this system is about 2-3 ns and the measurement range is 10 nanoseconds to miliseconds.

References

1. T. Stacewicz and M. Krainska, *Meas. Sci. Technol.* **8**(1997) 453-455.
2. Goro Nishimura and Mamoru Tamura, *Phys. Med. Biol.*, **48**(2003), N283-N290.
3. Qiyin Fang, Thanassis Papaioannou, Javier A. Jo, Russel Vaitha, and Kumar Shastry, *Rev. Sci. Instrum.*, **75**(2004), pp. 151-162.
4. D. C. Reynolds et al, *J. Appl. Phys.*, **88**(2000), pp. 2152-2153.
5. S. A. Studenikin and M. Cocivera, *J. Appl. Phys.*, **91**(2002), pp. 5060-5065.
6. W. Trabesinger, et al, *Rev. Sci. Instrum.*, **73**(2002), pp. 3122-3124.
7. Hamamatsu Photonics, "*Photomultiplier Tube*", Japan (1998).
8. Hamamatsu Photonics, "*R4457 Photomultiplier Tube Datasheet*", Japan (1991).
9. Hans Naus, Ivo H. M. van Stokkum, Wim Hogervorst, and Wim Ubachs, *Appl. Opt.*, **40**(2001), pp. 4416- 4426.
10. Joseph R. L., "*Principles of Fluorescence Spectroscopy*", Academy Press (1983).