Investigations of transient time-resolved spectral properties by using multi-fiber delay couple and optical multi-channel analysis

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Abstract: Investigations of the method and technique for measuring transient spectral time-resolved properties by using multi-fiber delay couple and optical multi-channel analysis were reported in this paper. The multi-fibers delay coupler constants of 5 pieces fibers with deferent lengths formed deferent time delay for passed each fiber light signal. The light signals were dispersed by a spectrometer, and then imaged in the focus plane of the spectrometer. Together with a fast optical-electric synchronization switcher, the light signals of the transient spectra were sampled, and processed by a microcomputer, finally formed a time-resolved spectrum. A time resolution of 5ns with wavelength range of 200-1100nm was reached using the method.

1. Introduction
In order to understand the time property of a transient radiation process such as a pulse lamp flashing, a high-energy laser or a high-speed pellet hitting a target it is necessary to measure the time-dependent spectrum of the transient light case. For a slowly light process, optical multi-channel analyzer (OMA) with a sensitive CCD device is a good tool for collecting and analysis the time-dependent spectra[1]. In the time range of pico-secend or less ps, streak camera is the best equipment for measuring the time-resolved spectrum. But in the range of ms to $\mu$s, we can find a few simpleness method to make the measurement. A rapid scan analyzer (RSA) with three array detectors of Reticon 64-element self-scanned, linear silicon photo diode arrays and a 16-element linear
A germanium photodiode array was developed for measuring single flashing Xe flash-lamp emission with a time resolution of 10.5 μs by C.E. Thompson et al.[2]. A new kind of measuring method for getting transient time-dependent spectrum using a rapid optical modulator was made by Yang et al.[3, 4], in which a time resolution of 400 ns has reached for measuring pulse flash lamp spectrum and a radiation from a target of crystal KCL hit by a rapid metal pill. In this paper we will present a new method and instrumentation for measuring the time-resolved spectrum in the range of ns based on multi fiber delay couple and multi-channel analysis.

2. Measuring method and instrument design

The principle of the method for measuring transient time-resolved spectrum is based on multi-fibres delay couple, in which a few of fibres with different length were used to transmit, couple measured light signals. Each fibre gets certainly light delay according to fibre length, and a group of fibres with different length form a multi-fibres delay coupler. When a transient light case passes through the delay coupler, the light process was separated a series segments in order of time. In the end of the coupler, the fibres were arranged a linear array according to the delay time. A faster light shutter cuts a piece of spectral process, then all of the light segments were coupled to a spectrometer, dispersed, formed 2-D spectral pattern on time order in the focus plane of the spectrometer. The spectral pattern was detected by a 2-D CCD array, converted and processed, formed time-resolved spectral pattern.

The instrumental diagram was showed in figure 1. Firstly the transient light signal was collected by a multi-fibers coupler (fibers) which constants of 5-20 pieces of fibers with different length. The length difference between two-fiber is the same of 1 or 2 m, the delay of the time is 5 or 10 ns between two fibers (delay time \( t = \frac{l}{c \cdot n} \), here \( c \) is light velocity in vacuum and \( n \) is the refractive index of the fiber. Note \( n = 1.6 \) (quartz), so \( t \) is about 5 ns for \( l = 1 \) m)

![Fig. 1. The diagram of the experimental setup](image)

The difference of length of each fiber is 1 m (or 2 m), it means the delay of time is about 5 ns (or 10 ns) between two fibers. The deferent time delay for passed each fiber light signal formed a time-difference, and then the light signals with certainly time-differences were coupled to the certainly parts of the slit of a grating spectrometer (G) by lens (L1). The different lights signals come from various fibers with special spectral information at various delay time were collected into the incident slit of the spectrometer according to a certainly space sequence. Then the series light signals dispersed by the spectrometer, and imaged in the focus plane of the spectrometer. Together with a fast optical-electric synchronic-switcher (Trigger), the light signals of transient spectra were sampled, detected by a 2-D CCD detector CCD (EG&G 1420, 510 x 510 units) that sits in the focus plane of the spectrometer followed an enhancer, a signal amplifier, an analog/digital converter A/D, and processed by a microcomputer (CMP), formed a time-resolved spectrum. A time resolution of 5 ns with wavelength range of
200-1100nm was reached using the method and the device in real measurement.

3. **Time-resolved spectral measurement**

In order to get good property of measured time-resolved spectrum, it needs to adjust the space property of the device. For multi-fibers delay coupler system, to adjust the position of multi-fiber coupler until to obtain the clearly spectral line for each fiber. Using a pulse YAG laser as the sample light source, five fibers of the multi-fibers coupler received the light signals at various space points from the laser beam (under the condition, the five spectral signals have the same spectral structure: wavelength, line width and line shape), formed the space-resolved spectra as figure 2. In which the laser source wavelength is 532nm, the transverse axis is wavelength, the vertical axis are intensities of the spectral lines, and the third axis is the space coordinate of each fiber at signal light beam space. The various intensities were carried since various couple conditions for each fiber.

![Fig. 2. 532nm YAG laser space – resolved spectra](image)

The time-resolved spectra of a R6G dye laser exited by Q-switch and double frequency pulse YAG laser were measured using the device. The spectral pattern showed as figure 3 in which the residuum pump laser and the dye laser were recorded in the same picture. The transverse axis is wavelength from 475nm to 624nm, the vertical axis is spectral relatively intensity, and the third axis is the time coordinate from 0 to 49ns. The time-resolution is 10ns which from the difference length between two fibers 2m. We found that the half of the pulse width is the same of 10ns for both of pump laser and the dye laser. But the dye laser has a little delay with the pump laser.

![Fig.3. Time-resolved spectra of YAG laser and R6G dye lase](image)

The stimulated Raman scattering of Acetone were exited by a Q-switching double frequency YAG laser. Then the Stokes emission from Acetone together with the residuum pump laser incident to a dye cell fill full with DCM dye solution. The stokes wave was enhanced in the dye solution, then the spectra were collected and measured as figure 4 in which the left line is the pump laser line; the middle is dye fluorescence of DCM, and the right is enhanced Stokes line of Acetone. The length difference of each fiber is 2m, so the time difference
Fig. 4. Time-resolved spectral of SRS of Acetone (time-solution) is 10ns. The transient emission spectra emitted from a metal Mo sample shocked by a pulse laser (1.06 μm) with a time-resolution of 5ns and an intensity-resolution of 18bits were made as fig. 5. The emission temperatures of the sample target Mo were calculated according to Planck emission law [5].

Figure 5. Time-resolved spectra of Mo shocked by a laser pulse

4. Result and discussions

A new method and instrumentation for measuring transient time-resolved was developed based on multi-fibres delay couple. A time resolution of 5ns, a spectral intensity resolution of 18bits with measuring wavelength range of 200-1100nm was reached. The system has good ratio of signal to noise, and stabilities in properties of wavelength, intensities and time.

Comparing with optical modulation method [3], the method of multi-fibbers delay has faster time resolution which easily reaching to less ns by using shorter delay fibre, simpleness in structures, and less price, but lesser time information because of limited number of fibres used in multi-fibres coupler. The method could be applied in the investigation range of transient optical-physical; optical-chemical and optical-biological time process.

5. References

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