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SPECTRORADIOMETRY OF PULSED OPTICAL RADIATION SOURCES

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FOREWORD

The following members of TC 2-21 "Spectroradiometry of Pulsed Optical Radiation Sources" took part in the preparation of this Technical Report. The TC comes under CIE Division 2 "Physical Measurement of Light and Radiation".

Kondo, H.	Japan	(Chairman)
Gavrilova, L. I. ¹⁾	CIS (then USSR)	
Goodman, T. M. ²⁾	Great Britain	
Gundlach, D. ³⁾	Germany, Federal Republic	
Lehman, R. F.	USA	
Lumenello, T. A.	USA	
Moore, J. R. ⁴⁾	Great Britain	
Sauter, G.	Germany, Federal Republic	
Vitel, Y. ³⁾	France	
Wychorski, P. F.	USA	

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2) from September 1988

3) from September 1987

4) up to August 1988

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SPECTRORADIOMETRIC MEASUREMENT OF PULSED OPTICAL RADIATION

SUMMARY

This technical report describes principles of measurement for the determination of the spectral and temporal characteristics of pulsed optical radiation sources. It contains detailed information on the characteristics of the individual elements of the apparatus required for accurate and precise measurement, a discussion on sources of error and a section on terminology, much of which is specific to this area of application. Finally, as an example of the application of the principles discussed, the details of a practical method of measuring the spectral energy distribution of a single flash from a pulsed xenon flash source are described in an appendix.

MESURE SPECTRORADIOMETRIQUE DU RAYONNEMENT OPTIQUE PULSE

RESUMÉ

Ce rapport technique décrit les principes de mesure pour la détermination des caractéristiques spectrales et temporelles des sources pulsées de rayonnement optique. Il contient une information détaillée sur les caractéristiques des différents éléments de l'appareillage requis pour une mesure juste et précise, une discussion sur les sources d'erreur et une partie sur la terminologie dont beaucoup est spécifique à ce domaine d'application. Dans l'appendice, comme exemple pratique de la technique présentée, une méthode est décrite pour mesurer la distribution spectrale d'une source non répétitive à tube à éclairs au xénon.

SPEKTRORADIOMETRISCHE MESSUNG GEPULSTER OPTISCHER STRAHLUNG

ZUSAMMENFASSUNG

Dieser technische Bericht beschreibt die Grundlagen der Messung zur Bestimmung spektraler und zeitabhängiger Eigenschaften gepulster optischer Strahlung. Er enthält detaillierte Angaben über die Merkmale der Teile einer Meßapparatur, wie sie für richtige und präzise Messungen notwendig sind, er diskutiert Fehlerquellen und nennt die für diese Anwendung spezifische Terminologie. Im Anhang wird als praktisches Beispiel der vorher diskutierten Techniken eine Methode zur Messung der spektralen Strahlungsverteilung eines Einzel-Xenon-Blitzes angegeben.

1. INTRODUCTION

1.1 General

Pulsed optical radiation is widely used in various fields and in various types of equipment including photographic electronic flash units, aircraft and emergency vehicle signal lighting, photocopiers, colorimeters, and pulsed luminous displays. As a consequence, an important need has arisen for measurements of the spectral and, in many cases, also the temporal spectral characteristics of pulsed optical radiation with the result that there is now a demand for a guide to the accurate and precise measurement of such characteristics.

The present technical report has been prepared to fulfil this demand. It should be noted, however, that because this is an area of rapid change and evolution, particularly in the field of detector technology, any attempt at this point to deal with specific techniques would be of little value and would run the risk that much of the information presented could be out of date by the time the report was published. Nevertheless, it was felt to be appropriate to include at least one example of an accepted measurement procedure. A description is, therefore, given of a specific method which has been found to be satisfactory for the measurement of pulsed xenon flash tubes. This should not be taken to imply, however, that it is the only method that will give satisfactory results.

In general, the report sets out to emphasise principles of measurement rather than to describe experimental techniques in detail.

This report complements CIE PUBLICATION No.63 (1984) THE SPECTRORADIOMETRIC MEASUREMENT OF LIGHT SOURCES [1], which deals with the measurement of continuous (i.e. non-pulsed) optical radiation. Many aspects of the apparatus and measurement techniques used are identical or very similar for both continuous and pulsed optical radiation and these common aspects are mentioned only briefly in the present report. Readers requiring further detail are advised to refer to the above CIE publication.

It should be noted that pulsed optical radiation can be produced by a variety of methods. For example:

- steady-state optical radiation with a chopper
- steady-state optical radiation with an electrical on/off circuit [e.g. flashing incandescent lamp or light emitting diode (LED)],
- directional steady-state optical radiation rotating about an axis perpendicular to the optical axis,
- discharge in xenon or some other gas mixture producing single or repetitive pulsed optical radiation.

NOTE: The coherence properties and narrow bandwidth of the radiation from pulsed lasers require a special measurement technique. Procedures for the measurement of the radiation from pulsed lasers are not, therefore, dealt with in the present report.

In the case of a source producing single, or non-repetitive, pulses all necessary information (spectral and/or temporal) must be obtained within the single pulse. It is usual to employ a discrete detector array. More options are available with repetitively pulsed sources. The spectral measurements can be made with either a discrete or a monolithic array, while the temporal measurements can be acquired by using a gated, micro-channel plate intensifier (so-called time slicing).

The methods of measurement described in this report can, theoretically, be applied to all types of pulsed radiation source. However, for pulse durations less than about 10^{-6} s, the detector frequency response (response time) must be extremely fast to follow the very rapid change in the intensity of radiation and the associated electronic circuitry must not affect the detector frequency response characteristics.

With regard to the accurate and precise measurement of the spectral and/or temporal spectral characteristics of pulsed radiation sources, this technical report:

- (1) explains principles of measurement,
- (2) gives information about the essential characteristics of the different instruments and components involved,
- (3) presents, as an example, a practical method which has been used successfully to measure the spectral characteristics, over a wavelength range from near ultraviolet to near infrared, of incoherent pulsed xenon flash sources with an effective flash duration (see 1.3 Terminology) no greater than about 100 ms.

1.2 Differences between pulsed and continuous sources

Because the radiation from a pulsed source can have a very short duration, special equipment may be required and special precautions may need to be taken. The following measurement techniques are offered as examples.

1.2.1 Monochromator systems

Where a monochromator system is employed, it is necessary to make measurements of pulsed sources on a wavelength by wavelength basis. This is because, in most cases, the radiant output from a pulsed source varies very rapidly, increasing from 0 to 100% in a few tens of microseconds or even less, and, within such a short period of time, a monochromator cannot physically be scanned over more than an extremely narrow fraction of the spectrum. During a single pulse, therefore, a measurement of a radiometric quantity (such as spectral radiance or irradiance) can in practice only be obtained for a single wavelength setting, so that to obtain the complete spectral power distribution it is necessary to operate the pulsed source repetitively, making measurements at a series of discrete wavelength settings until the desired spectral range has been covered.

The use of this wavelength by wavelength method requires a photodetector system with good long-term stability and a pulsed source with negligible short and long term pulse-to-pulse variability. Modern photodetector systems can indeed be very stable provided they are chosen with care. The same cannot be said, however, for many of the pulsed sources currently found in science and industry. The short term pulse-to-pulse variability is likely to be 1% at best and the long term variability, several per cent, even when a carefully designed power supply is used. In the case of commercially available pulsed sources, such as photographic electronic flash units, the short term flash-to-flash variability can be several per cent with long term variability correspondingly higher.

For this reason, the use of a stable monitor detector is recommended in order to check and compensate for the variation in radiant output from flash to flash. No monitor, of course, can compensate if there are changes in the relative spectral power distribution of successive flashes. Ideally the spectral responsivity of the monitor detector should match the spectral responsivity of the measuring instrument.

1.2.2 Polychromator systems

If a pulsed radiation source is to be measured with an uncertainty of less than a few percent then it is essential to make a simultaneous measurement over the entire wavelength range. For such a measurement, a polychromator, an array detector (see 1.3 Terminology) and a matching data acquisition system are necessary.

When measuring the temporal characteristics of a pulsed source it is essential that the detector system should have a fast frequency response (short response time) so that it can follow rapid changes in the intensity of the radiation. This is not strictly necessary if only time-integrated measurements of the spectral energy distribution are required, provided that the output of the detector system is proportional to the time integral of the radiant power incident upon the detector.