

9.16 Low-Light-Level Detection

Lately, low-light-level detection is becoming increasingly important in various scientific fields. In particular, low-light-level detection techniques are in greater demand in such studies as Raman scattering, Rayleigh scattering, biology, analytical chemistry, astronomy and fluorescence analysis. The detection techniques using photomultiplier tubes include the analog DC method, analog pulse method and digital method (photon counting). Of these, the photon counting is extremely effective in low-light-level detection. The excellent characteristics of photomultiplier tubes such as high gain and low noise can be fully utilized in this field.

9.16.1 Overview

Low-light-level detection utilizing the superior signal-to-noise ratio of photomultiplier tubes is being applied to diverse fields including Raman scattering, biology, chemical analysis and astronomy. Figure 9-67 shows the block diagram of a laser Raman spectrophotometer.⁴⁴⁾

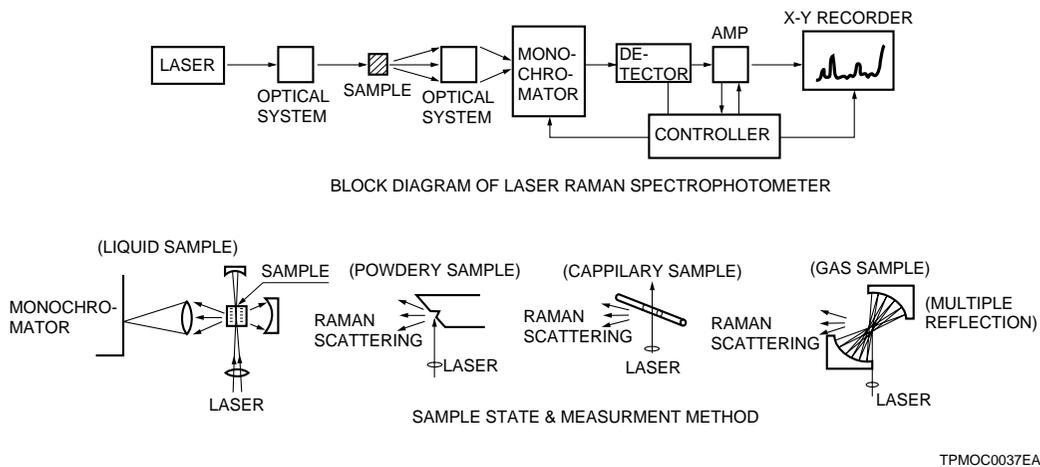
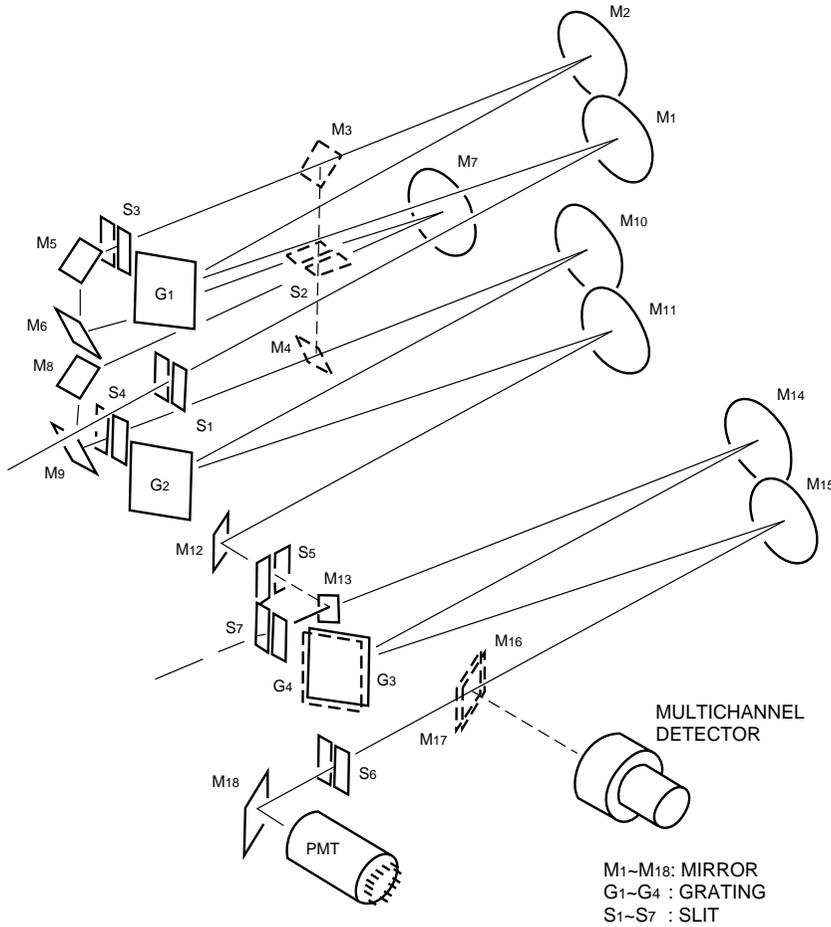


Figure 9-67: Block diagram of a laser Raman spectrophotometer

With recent advancements in laser technology, life science research such as a study of local protein structures utilizing Raman scattering is rapidly progressing. Because Raman scattering has an extremely low light level as compared to Rayleigh scattering (with the same wavelength as that of the excitation light), a high-quality monochromator with minimum stray light and a high-sensitivity detector must be used to separate the Raman scattering from extraneous light. A common monochromator used in Raman spectrophotometry is a double-monochromator equipped with a holographic grating or, in some cases a triple-monochromator with filter mechanism. Raman spectrophotometry requires such a complicated optical system that the incident light on the photomultiplier tube will be exceptionally low. For this reason, the photon counting method which ensures excellent signal-to-noise ratio and stability is frequently used. The monochromator and optical system used in Raman spectrophotometry must provide "minimum stray light", "high resolution" and "good light-collection efficiency". Figure 9-68 shows the optical layout⁴⁵⁾ of a laser Raman spectrophotometer. This instrument usually uses a photomultiplier tube specially selected for photon counting.



TPMOC0038EB

Figure 9-68: Optical layout of a laser Raman spectrophotometer

9.16.2 Characteristics required of photomultiplier tubes

The following characteristics are required of photomultiplier tubes used in photon counting.

- a) Less broadening of pulse height distribution, in other words, superior single photoelectron resolution (a sharp valley should exist so that the effects of photomultiplier tube sensitivity drift and supply voltage fluctuation can be reduced when the tube is operated over extended time periods.
- b) Less dark current pulse
- c) High gain

If linear counting is essential up to a high light level, a fast-response photomultiplier tube must be used. In this case, it is recommended that photomultiplier tubes with a linear-focused dynode or circular-cage dynode be used.