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Mössbauer velocity calibration with an (Al, Ga)As laser diode

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(Received 23 November 1982; accepted for publication 10 January 1983)

Velocity calibration of a Mössbauer spectrometer operating in a constant acceleration mode has been obtained with a Michelson interferometer using an (Al, Ga)As laser diode. The very small size of the laser diode makes it possible to construct a very compact optical system for velocity calibration.

PACS numbers: 07.85 + n, 42.60.Kg

Considerable progress in the development of double heterostructure (Al, Ga)As laser diodes in recent years made it possible to use them in various applications.[1,2] They are used in fiber-optic communications systems, and in particular, in optical video disk readout.[3,4] The (Al, Ga)As lasers are currently the most efficient sources of coherent light in the wavelength range $780 < \lambda < 900$ nm. A useful property is that they are very small—the maximum dimension of a laser housing is of the order of 1 cm. In this note we describe the application of the (Al, Ga)As laser diode for velocity calibration of a Mössbauer spectrometer.

The accuracy of hyperfine parameters derived from Mössbauer spectra depends on the precision with which the velocity scale of a Mössbauer spectrometer is calibrated. Usually the calibration is made with standard absorbers, e.g., with an iron foil, for which the positions of absorption lines are well known.[5] Such a calibration technique, however, has some drawbacks. Standard absorbers cover the velocity range from 0 to about $\pm$ 10 mm/s. For many Mössbauer nuclei, velocities of some centimeters/second are required and here it is not justified to assume the linearity of the transducer. Additional errors in velocity calibration may be caused by the geometry of the experimental setup.[6] The drawbacks of the velocity calibration with standard absorbers can be avoided by using optical methods based on the observation of either moiré[7] or interference[8–10] fringes. In the latter technique a Michelson interferometer with a He–Ne laser is used. The length of a typical He–Ne laser is about 35 cm. Thus, the linear dimensions of an optical system are comparable with the dimensions of a Mössbauer spectrometer itself. This makes the alignment of the system with a transducer working in vertical geometry quite cumbersome. The use of a laser diode offers the possibility of constructing a much more compact optical system which is also easier to align.

We constructed a conventional Michelson interferometer in which a He–Ne laser is replaced by a (Al, Ga)As laser diode which forms part of a collimator pen. A collimator pen[11] consists of a laser diode and a PIN photodiode, optically coupled to the rear emitting facet of the laser. In addition, it has a lens system which collimates the divergent beam and corrects for astigmatism. The photodiode is used as a sensor which keeps the power output constant. One mirror of the interferometer is fixed and the other is placed on the back side of the transducer. The emission spectra, recorded with a Spex monochromator, of the laser diode set on power output 1.7 mW and of a 0.5-mW He–Ne laser[12] are shown in Fig. 1. The peak emission wavelength of the laser diode is 836.0(0.2) nm set on power output 1.7 mW, while that of the He–Ne laser is 632.8(0.2) nm. The full widths at half-maximum of the envelope of the emission lines from the laser diode and

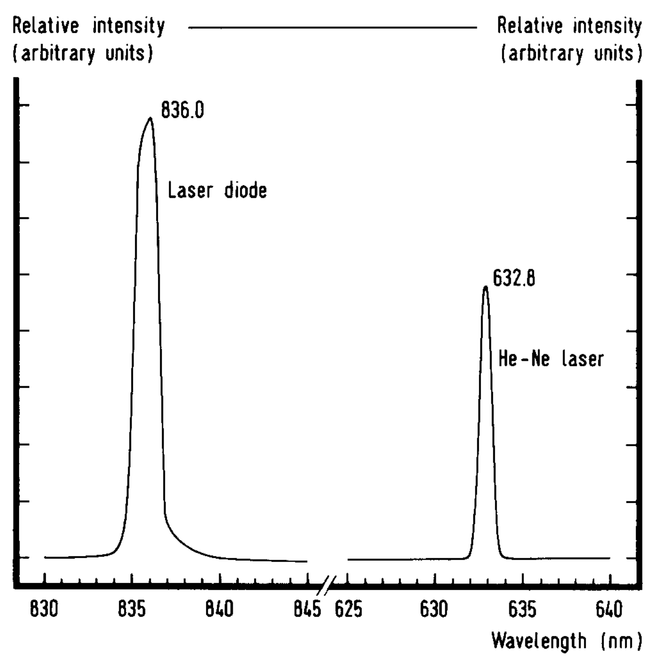

FIG. 1. Emission spectra of the Philips collimator pen 56390 laser diode set on power output 1.7 mW (a), and the 0.5-mW Spectra-physics (model 155) He–Ne laser (b).

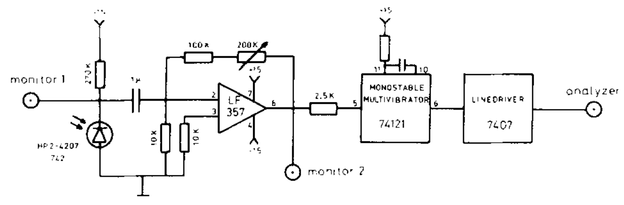

FIG. 2. Electronic circuit of the light detector.

the He–Ne laser are 1.5 and 0.8 nm, respectively. The power supply of the laser diode must be of very good quality,[13] so that the laser diode is protected against very brief transients which can cause irreversible device failure. As a light detector we use a photodiode followed by a current-to-voltage converter (Fig. 2). The alignment of the Michelson interferometer using the laser diode can be accomplished in two steps. First, the fixed mirror is temporarily covered with a light absorbing plate. The system is now adjusted in such a way that for monitor 1 (Fig. 2) a minimum dc level is obtained. Second, the movable mirror is covered with the same plate and the fixed mirror is adjusted so that once again a minimum dc level is obtained. Then a symmetric sawtooth voltage is applied to the transducer and a pattern from monitor 2, similar to that shown in Fig. 3, is observable on an oscilloscope. This pattern demonstrates that the interferometer is working properly.

In order to determine the reliability of the system, we measured the Mössbauer spectrum of an iron foil 0.009 mm thick and the corresponding velocity spectrum (Fig. 4). From the latter spectrum, velocities corresponding to every channel were calculated and fitted to a polynomial of eighth degree. The polynomial constants are now used as input parameters to a computer program which linearizes the velocities of both halves of the spectrum and folds the mirror Mössbauer spectra.[14,15] The positions of Zeeman lines obtained from a computer fit with six independent Lorentzian lines are $-5.413(0.001)$, $-3.182(0.001)$, $-0.952(0.001)$, 0.728(0.001), 2.958(0.001), and 5.198(0.001) mm/s. They are in a good agreement with values from the literature: -5.418, -3.182, -0.946, 0.734, 2.970, and 5.206 mm/s.[5,16]

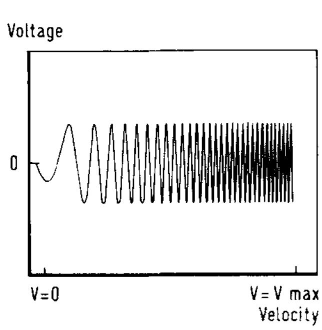

FIG. 3 Electrical signal from the current-to-voltage converter when the Mössbauer transducer moves with a constant acceleration.

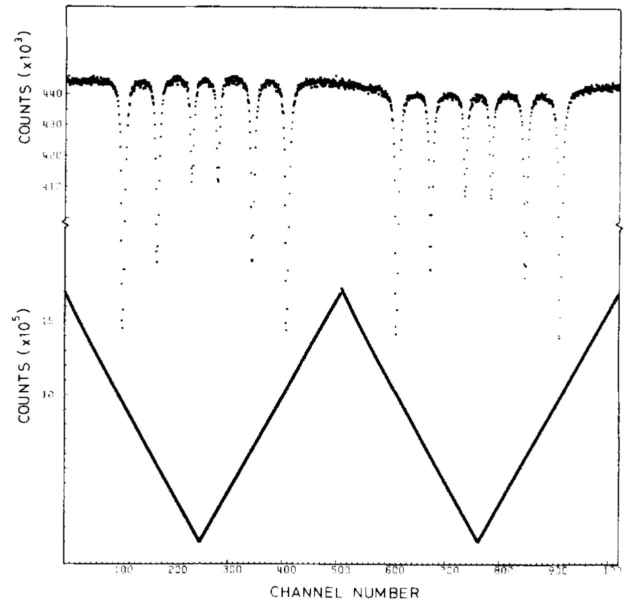

FIG. 4. Room temperature Mössbauer spectrum of an iron foil 0.009 mm thick (a) and the corresponding velocity spectrum (b). The source used was $^{57}Co(Rh)$.

The authors are greatly indebted to Dr. J. C. J. Finck (N. V. Gloeilampen Fabriek Philips) for supplying the collimator pen and to Prof. dr. E. de Boer for critically reading the manuscript.

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