

A CONVENIENT DOPPLER SHIFT METHOD FOR DETERMINING THE VELOCITY OF A FAST ION BEAM

S. Huldt, L.J. Curtis and R.M. Schectman

Department of Physics and Astronomy, University of Toledo, Toledo, Ohio, 43606, USA

and

Department of Physics, University of Lund, S-223 62 Lund, Sweden

Résumé - On décrit une méthode de détermination de la vitesse d'un faisceau d'ions qui est basée sur l'effet Doppler. Quelques applications sont présentées.

Abstract - A convenient method for determining the velocity of a light emitting fast ion beam utilizing fore and aft Doppler shifts is described, and applications are presented.

A convenient method for determining the velocity of an ion beam utilizing fore-aft Doppler shifts has been developed and tested. The method easily allows measurements to within at least 1% with a geometry compatible with lifetime measurements. The method utilizes two mirrors which contain central apertures to allow the beam to pass through. These can be inserted into the beam and adjusted so as to illuminate the slit of a spectrometer which views the beam at 90°. No change in the monochromator or target position need be made. A schematic diagram of the experimental arrangement is shown in Fig. 1.

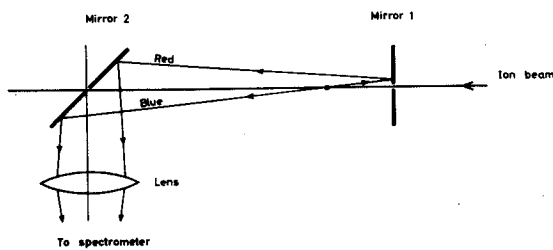


Fig. 1 Experimental arrangement

Mirror 1 is tilted at 45° so that light in a forward cone is reflected into the spectrometer. Mirror 2 is set perpendicular to the beam so that light in a backward cone, centered at 180° to the beam direction, is reflected back along the beam onto mirror 1, and thereafter into the spectrometer. Thus three pencils of light enter the spectrometer; one from the forward light which is blue shifted to $\lambda_B = \lambda_0 \gamma(1-v/c)$; one from the backward light which is red shifted to $\lambda_R = \lambda_0 \gamma(1+v/c)$; and one emitted at 90° to the beam which is essentially unshifted

at $\lambda_0 \gamma$ (here $\gamma = (1-v^2/c^2)^{-1/2}$). By appropriate adjustment of the mirrors all three wavelengths can be seen by the spectrometer. Clearly the red and blue shifted images formed by the plane mirrors are at different distances from the spectrometer, which vary with the position of the emitted light along the beam. Thus these two images cannot be brought into simultaneous focus and a small range of angles about 0° and 180° is included. However both of these effects can be made negligibly small by choosing the geometry of the system appropriately. Neglecting the relativistic doppler shift [1], the velocity of the beam is given by

$$v/c = (\lambda_R - \lambda_B) / 2\lambda_0. \quad (1)$$

Doppler shifts have been used earlier in the determination of beam velocities [2-4], but the fore-aft geometry suggested here has a number of advantages. It is directly compatible with the detection geometry employed in carrying out mean-life measurements. It gives the largest Doppler shift and the smallest Doppler broadening of any angles chosen. Relativistic corrections to Eq (1) enter only in third order [1] with this geometry. The method also provides built-in checks of the alignment through tests of the symmetry of the fore and aft peaks about the central peak. It is very insensitive to misalignment of the mirrors relative to the beam (<0.4% error in velocity for a 5° misalignment) since this effect is of second order in angular error. In fact, the mirrors were in some cases deliberately misaligned slightly in order to improve the relative intensity of the red shifted peak. Identification of the fore and aft peaks is expedited by the fact that they are narrower than

the central peak which is broadened by Doppler shifts. Finally, the technique does not require an absolute wavelength calibration of the monochromator since only the wavelength difference $\lambda_R - \lambda_B$ is required; thus, only the dispersion of the instrument need be known.

Beams of He^+ of energies from 150 to 200 keV were obtained from the University of Toledo Van de Graaff generator. Figure 2 shows the central and

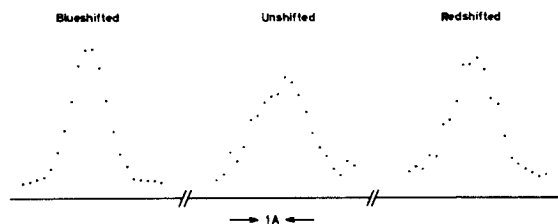


Fig. 2 Dispersed spectrum of the 3888 Å Helium I line with this experimental arrangement.

the shifted peaks for the 3888 Å He line. The method was used for energy calibration of the accelerator, and for determining the energy loss in carbon foils as a function of foil thickness. The results of the latter measurement is shown in fig. 3, and compared with published values [5] indicated by the solid curve, demonstrating the reliability of the technique.

The use of the emitted light to determine beam velocities is attractive for a number of reasons. Such a measurement averages over the emitting particles including wider angles of scattering

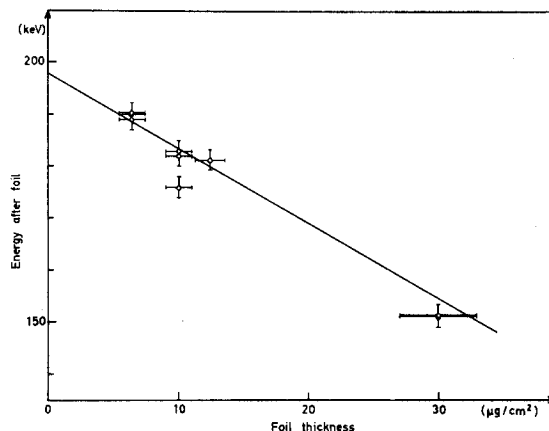


Fig. 3 Measurement of energy as a function of foil thickness for a monoenergetic beam.

which are often excluded by other techniques (for example, the electrostatic analyzer, which interrogates only a narrow undeflected portion of the beam). Moreover, it is the light-emitting particles upon which lifetime measurements are made, and it is appropriate that velocity measurements be made on the same sample as are the decay curve measurements. Finally, by spectrally resolving the light, one also measures the velocity of a particular charge stage, excitation level and spin stage. If there were subtle differences among these parameters, this method would provide a very sensitive means of detecting them, and for studying such effects.

Bibliography

- [1] Because of its subtractive nature, all even terms in the relativistic expansion for $\lambda_R - \lambda_B$ in powers of v/c cancel, and the first correction to Eq(1) is of third order.
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