magnet could provide useful damping. Typically we use the ETFC by first collecting a set of pictures at a single wavelength, and then collecting an interlaced series of pictures by switching the ETFC. The switching is activated when the vidicon output changes above some preset threshold; separate thresholds are used for initial and subsequent switching.

In addition to alternation of interference filters, the ETFC is also well suited to switch polarizers for spatially resolved linear or circular dichroism measurements, since a maximum time is spent with the polarizer in the desired configuration. In this way, the duty cycle is much better than a rotating wheel.

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Spin sensitivity of a channel electron multiplier

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We report direct measurements of the sensitivity of a channel electron multiplier to electrons with different spin orientations. Four regions of the multiplier cone were examined using polarized electrons at 100-eV incident energy. Pulse counting and analog modes of operation were both investigated and in each case the observed spin effects were less than 0.5%.

Channel electron multipliers (CEMs) have become important and common detectors in a broad range of applications, especially those involving the detection of electrons. Many of these investigations, in particular electron-atom and electron-surface scattering experiments, are being extended to include polarized electron beams and electron-spin-polarization detectors. In all experiments to date, the CEMs have been assumed insensitive to the spin of the incident electron. A direct test of the CEM spin sensitivity, therefore, appeared desirable. Further motivation came from experiments by Register *et al.*,[1] who discovered an unexpected asymmetry in the intensity of electrons scattered by excited-state Ba atoms as a function of the excitation laser polarization. This asymmetry could arise from a spin dependence in the detection efficiency of the scattered electrons.[2]

A CEM functions[3] as a detector and amplifier through the process of secondary electron emission. An electron incident on the inside surface of the front cone will be detected if it causes the emission of secondary electrons, which are accelerated by a high voltage placed across the resistive CEM until they strike the CEM surface causing further secondary emission. The process is repeated several times with the final gain being the product of the secondary-emission yields. For high incident currents, typically 10^6 electrons per second and more, the device is generally used as an analog amplifier, with a low gain as determined by a low accelerating potential. When small incident currents must be detected the CEM is used in a pulse counting mode, usually at a sufficiently high voltage to ensure a large degree of gain saturation. That is, the output pulse heights have a characteristic amplitude well separated from the prevailing noise level, allowing a noncritical setting of the pulse-height discriminator. In this case, small variations in CEM gain have little effect on the count rate and measured intensity, in contrast to the analog mode where the measured output current is linearly proportional to the gain.

The secondary yield is largely dependent on the primary electron energy, incidence angle, and CEM material. However, if the yield also changes with the spin of the incident electron, the CEM gain would be spin sensitive. Spin-dependent interactions between electrons and solid surfaces are well known for both magnetic targets, where the exchange interaction plays a role, and high-Z materials, where the spin–orbit interaction becomes significant.[4] Although CEMs are fabricated from nonmagnetic glass, they do have a heavy lead doping[3] so a spin–orbit-related sensitivity to incident electron spin would not be surprising. Supporting evidence can be found in experiments in which polarized electrons are made obliquely incident on the surface of high-Z materials. For example, in low-energy electron diffraction from tungsten,[5] the coefficient for the specular reflection of electrons with one spin orientation can be as much as nine times that of oppositely oriented electrons.

It is important to recognize the consequences of the symmetry of spin–orbit-induced scattering asymmetries. If the spin–orbit interaction produces an enhanced cross section for scattering to the right for spins oriented normal to the scattering plane, then oppositely oriented electrons will have an equally enhanced cross section for scattering to the left.[4] This sorting, to the right and left, of electrons with opposite spin orientation could cause an incident electron to penetrate the surface more or less deeply. For example, an electron with spin oriented up relative to a horizontal scattering plane might travel more or less deeply into a vertical high-Z surface inclined at an angle to the incident beam. The probability of low-energy electrons escaping and becoming secondaries depends upon the depth at which they originate and, therefore, might depend upon the spin orientation of the incident electrons. Thus, a difference, if it exists, between the CEM gain for spin-up and spin-down incident electrons should be observable when the beam strikes the side of the cone, where the surface normal subtends an angle of $\approx 70°$ with respect to the incident electron's momentum vector. Furthermore, if this effect is significant, reflection symmetry would require that a change in sign in the spin asymmetry would occur on going from one side of the cone to the other.

In order to investigate the spin sensitivity of a CEM, an existing apparatus designed for polarized electron, polarized atom scattering experiments[6] was modified to allow accurate location of a polarized electron beam on the front cone of a CEM.[7] The apparatus is depicted in Fig. 1. Longitudinally polarized electrons were produced from a NEA GaAs source by photoemission with circularly polarized light from a linearly polarized diode laser and Pockels cell.[8] The handedness of the photons and, therefore, the spin orientation of the photoelectrons, was switched by application of a high-voltage square wave to the cell. A 90° spherical electrostatic deflector changed the direction of the electron beam but not the spin direction, producing electrons polarized transversely to the electron momentum. These were transported through a series of optics and a small (0.45-mm) aperture at the same potential as the CEM cone to produce a nominally collimated ($\lesssim 0.5°$) 100-eV beam. The aperture, positioned 3 mm in front of the cone, both reduced the electron current and localized the electrons to a small region of the cone. The CEM, shielded within a box mounted to a three-axis manipulator, could be scanned across the beam. Profiles of electron current measured in this way, in both analog and pulse modes, showed good final beam definition.

We define a spin sensitivity asymmetry A_{cem} by the usual relationship

$$A_{cem} = (1/P_e)(I_\uparrow - I_\downarrow)/(I_\uparrow + I_\downarrow), \quad (1)$$

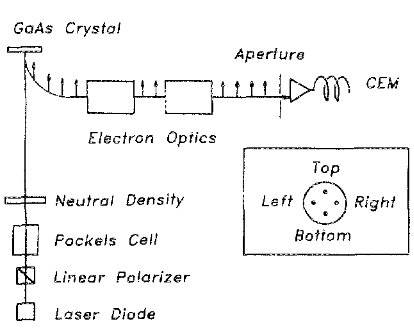

FIG. 1. Schematic of the apparatus. Inset: front view of the CEM cone showing the four measurement positions "right," "left," "top," and "bottom."

where $I_\uparrow$ ($I_\downarrow$) is the signal intensity for spin-up (-down) electrons, and P_e is the incident electron polarization, determined to be 23% $\pm$ 2% from 100-kV Mott detector measurements. The asymmetry was measured in both the pulse and analog modes. In the pulse mode, two gated scalars counted amplified and discriminated CEM pulses for up and down spin directions, switched at 200 Hz. The CEM was operated at a voltage of 2500 V, which resulted in a pulse-height distribution that was unsaturated. The discriminator setting was chosen by selecting a region of the pulse-height distribution where pulse-height variations would cause greatest change to the count rate. This somewhat unconventional setup was used in order to enhance any spin-dependent effects, the assumption being that for operation in the normal saturated mode, spin effects could only be less pronounced. If the pulse-height distribution were saturated, variations in the gain arising from spin effects would be masked because all pulses would have nominally the same saturated height.

In the analog mode, the CEM output current was amplified with an electrometer floating at the CEM voltage (2300 V in this case), and converted to a countable pulse train with an isolated voltage-to-frequency converter. The polarization was reversed at 23 Hz in this case due to the slow response of the electrometer. Count rates were kept below 10 kHz for pulse counting, and the incident beam current was kept sufficiently small (<0.1 pA) in the analog mode to be within the CEM linear dynamic range. This was accomplished with the aid of neutral density filters in front of the laser diode.

Four positions of the electron beam on the CEM cone were considered: left, right, top, and bottom, as seen by the incoming electrons (see Fig. 1, inset). All were 2.5 mm from the center of the cone, which has an active diameter of approximately 10 mm. The resulting asymmetries were adjusted as shown in Eq. (1) for the incident electron polarization, which was perpendicular to the left–right axis.

For operation of the CEM either as an analog current amplifier or as a pulse counting device, the asymmetries measured in all four positions were less than 0.5%. Furthermore, the asymmetries on the left and right sides of the cone never differed by more than 0.05%. We conclude from this that the sensitivity of a CEM to the spin of an incident electron is certainly less than 0.5% and is perhaps even smaller. This was found despite operation of the CEM in regimes expected to maximize possible spin-dependent effects, i.e., in an unsaturated pulse counting mode and in the analog mode.

Since we have considered only one energy, angle of incidence, and cone bias, larger spin dependencies cannot be completely ruled out. Nevertheless, in light of the present results, and considering the broad energy and incident angle dependencies generally seen in spin–orbit scattering effects, it is unlikely that much larger effects would be found.

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Rotational and translational cooling of molecular ions produced in a slot nozzle

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Excimer laser drilling has been used to cut a 20-μm by 5-mm slot in the end of a closed Pyrex tube. The slot nozzle thus formed is suitable for production of a corona-excited supersonic expansion. The performance of the device has been characterized by recording the spectrum of the N_2^+ B–$X(0, 0)$ band at high resolution with the optical axis parallel to the slot and with the axis perpendicular to the slot (simulating a standard pinhole nozzle expansion) for comparison. The spectral lines recorded parallel to the slot nozzle are found to have a Doppler width such that a spin doubling of 0.06 cm^{-1} is resolved, while the pinhole-type spectrum resolves spin doubling of 0.09 cm^{-1}. The slot nozzle also enhances the intensity of the spectrum, reducing recording time from 10 to 2 min, while maintaining the same approximate rotational temperature of 20–40 K.

In 1983, Droege and Engelking demonstrated that a corona discharge, when struck through the throat of a pinhole nozzle used to produce a supersonic expansion, produces a bright source of rotationally cold, electronically excited, free radicals.[1] The inexpensive and reliable design of this device has attracted the attention of other workers as well, and it has since been used as a convenient source for recording the emission spectra of stable molecules,[2] polyatomic free radicals,[3] hypovalent molecules,[2] molecular ions,[4] and weakly bound clusters.[5] Engelking has recently published the details of construction of this device together with an analysis of the associated electronics and a brief description of the chemistry of such discharges.[6]

Attempts to use this device for high-resolution emission studies have, however, met with considerable frustration.[2,7] If helium is used as the carrier gas in the supersonic expansion, the relatively high velocity of helium atoms expanding from the nozzle impart an undesirable velocity structure to the observed emission lines. This velocity structure effectively broadens the Doppler width of the emission lines to that of atomic helium, degrading the resolution of the observed spectrum by a factor of 3 or more. In addition, clustering near the center of the expansion may impose an asymmetric or bimodal line shape on the features of interest. While such spectra may be usable, experience has shown that vital features of molecular spectra, features which may be crucial to a proper analysis, are often compromised by inadequate resolution.

Using argon as a carrier gas will, of course, suppress such velocity structure. It will also reduce the effectiveness of rotational cooling and promote clustering, which may not be desirable. Furthermore, the chemistry involved in the production of some excited ions (e.g., SO^+) may demand the use of pure helium as a carrier gas. Skimming the jet, which should also reduce the Doppler width, reduces the emission intensity intolerably as well as changing the electrical characteristics of the discharge.

Recently, reports have appeared detailing the advantages of using a slot-shaped nozzle in reducing the Doppler width in supersonic expansions when recording infrared absorption spectra.[8,9] When viewed with the principal optical axis parallel to the axis of the slot and slightly downstream, such nozzles increase the optical density of the source above that provided by a pinhole nozzle and so improve the signal level of the recorded spectra. In addition, because flow near the center of the slot is collisionally self-collimated, the apparent Doppler width of the source viewed in this way is reduced to a value below that of the bulk gas at room temperature.[8,9]

This note reports the use of such a slot nozzle in producing a corona-excited supersonic expansion. We present the method of construction of such a device, and we document the brightness of emission compared with other sources and the rotational and translational cooling of molecular emission that we have observed at high resolution.

Because the nozzle must be constructed entirely of elec-

