The Effect of Ghost Reflections in Laser Wire Measurements

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Abstract: An analysis of the effect of ion neutralizations arising from stray reflections of the laser beam is presented. It is found that the portion of the laser beam reflected from the vacuum chamber exit window makes a negligible contribution to the total neutralization yield.

In the laser wire technique for beam profile measurements, a laser beam is focused onto the H^- beam. A measure of the neutralization fraction provides information about the ion density in the portion of the beam that overlaps the laser beam. In addition to the primary illumination by the focused laser beam, it is also possible for the ion beam to be illuminated by light reflected by the exit window. The effect of this "ghost" reflection is calculated below and is found to be minimal.

If saturation effects can be ignored, then the number of neutralized ions will be proportional to the geometric overlap of the ion beam and laser beam:

$$S = \eta \int dt \iiint dx\,dy\,dz\, n_I(x,y,z,t)\, n_p(x,y,z,t), \tag{1}$$

where $n_I(x,y,z,t)$ and $n_p(x,y,z,t)$ are the ion and photon densities, respectively and η is a constant of proportionality. The ion beam propagates in the *z*-direction and is assumed to be radially symmetric. The ion density may then be described as

$$n_I(x,y,z,t) = \frac{N_{ION}}{(2\pi)^{\frac{3}{2}} \sigma_z \sigma_I^2} \exp\left[-\frac{x^2+y^2}{2\sigma_I^2}\right] \exp\left[-\frac{(z-\beta ct)^2}{2\sigma_z^2}\right]. \tag{2}$$

The laser beam propagates in the *x*-direction and is also assumed to be radially symmetric. The photon density in this case is given by

$$n_p(x,y,z,t) = \frac{N_{PHOTON}}{(2\pi)^{\frac{3}{2}} \sigma_p^2 \sigma_x} \exp\left[-\frac{(y-d)^2+z^2}{2\sigma_p^2}\right] \exp\left[-\frac{(x-ct)^2}{2\sigma_x^2}\right], \tag{3}$$

where *d* is the displacement of the laser beam relative to the center of the ion beam. With these densities, the signal is found to be

$$S = \frac{\eta n_{ION} n_{PHOTON}}{2\pi v \sqrt{\sigma_I^2+\sigma_P^2}\sqrt{\sigma_I^2+\sigma_x^2}} \exp\left[-\frac{d^2}{2\left(\sigma_I^2+\sigma_P^2\right)}\right]. \tag{4}$$

Our interest here is not the primary signal itself, but any signal that might be due to the portion of the laser beam that is reflected off of the exit window. The photon density will be much lower in a reflected beam, not only because most of the energy passes through the window, but also because the reflected beam will be much larger when it once again reaches the ion beam. Shown in Fig. 1 are plots of the primary signal and of the "ghost" signal as functions of the laser beam displacement, *d*.

For these plots, σ_I was set to 1 mm. For the primary signal, σ_p was set to $\sigma_I / 4$. And for the secondary signal, σ_p was set to 15 mm. The basis for this choice was a symmetric geometry in which the laser beam is focused at or near the ion beam and the value of σ_p at the entrance and exit windows is 7.5 mm. The reflected spot (actually, two similarly sized spots) is twice as large at the center of the chamber. It is also assumed that only 7% of the signal is reflected at the exit window. The plot is normalized, so that the primary signal reaches a maximum value of 1.

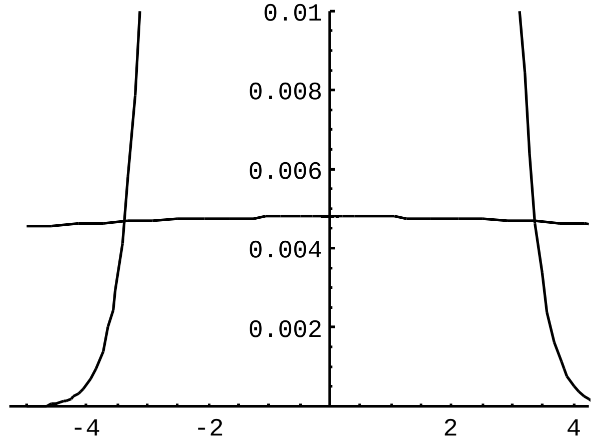

Fig. 1. Primary and "ghost" signals plotted as functions of the laser beam displacement.

Two points should be made here. First, the ghost signal can be considered a background signal that is nearly independent of the laser beam displacement. So even if the ghost reflection is not perfectly centered, it is not the case that the contribution from this effect will be significantly larger for one part of the scan than for others. Also, the effect is fairly small, limited to less than 0.5% of the peak primary signal. Indeed, it is not until the laser beam displacement exceeds $3\sigma_I$ that the ghost signal rivals the primary signal. This can also be seen (or not seen) in Fig. 2, which shows a plot of two curves: the primary signal and the primary and ghost signals added together. The fact that the two curves are nearly identical suggests that the effect of the ghost is minimal.

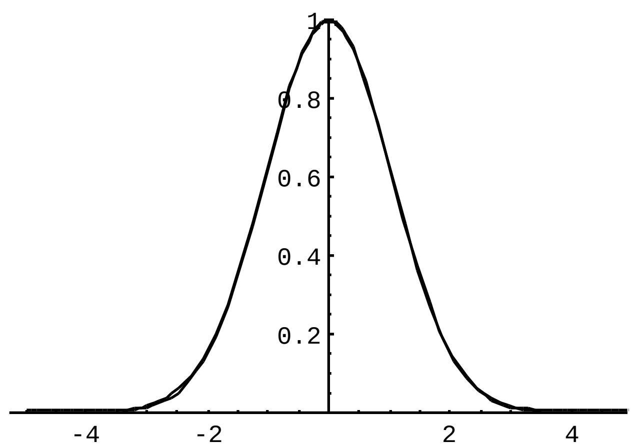

Fig. 2. Primary and "primary + ghost" signals plotted as functions of the laser beam displacement.