Stable Neon Emission from a Gas Field Ion Source

FHM Faridur Rahman and John Notte
Carl Zeiss SMT Inc., 1 Corporation Way, Peabody, MA 01960 USA

Shida Tan and Richard H. Livengood
Intel Corporation, MS: SC9-68, Santa Clara, CA, 95054

The capabilities of the Gas Field Ion Source (GFIS) have been well established[1] and most recently commercialized as the helium ion source of the ORION helium ion microscope[2,3]. The helium GFIS was pioneered as an extension of the Field Ion Microscope (FIM), which was developed 55 years ago. We therefore attempted to use neon gas in the FIM to better understand the prospects for commercializing a neon GFIS. Motivating this work is the prospect of a single GFIS that could be used for both imaging (with helium) and sputtering (with neon).

The neon FIM was outfitted with an MCP image intensifier and a CCD camera for recording still images and video. To study the longer timescales we employed time lapse techniques to economize the acquired data when the time spanned over several days. For shorter timescales we used fast frame acquisition at rates approaching 200 Hz for time periods of about 30 seconds. All video and images were analyzed with imageJ software[4]. For each frame acquired at time, t, the individual emission sites were scrutinized to ascertain the center of brightness $X(t),Y(t)$, as well as the mean brightness $B(t)$ for that site.

Generally, we observed various neon emission instabilities occurring at a variety of timescales. At the longest timescales (days) we would occasionally see the emitter lose atomic emission sites – leading to an abrupt termination of the neon ion beam. This was attributed to global emitter shape changes resulting from impurities in the gas supply in conjunction with the reduced operating voltage which neon requires. At intermediate timescales (hours) we observed some small current fluctuations (< 10%) that might be attributed to gas supply modulations through the dynamic adsorption and desorption of distant non-neon adatoms. At the fastest timescales (~10 sec to ~10 ms), we observed two dynamics that we believe are heretofore undocumented in the literature. First, we see strong evidence of bi-stable and even multi-stable states of emission intensity. Specifically, we observe the emission jumps back and forth between one relatively stable emission level and another relatively stable emission level. Second, we observe that the location of the emission site (as inferred from the FIM image) apparently moves between two or more relatively stable emission locations.

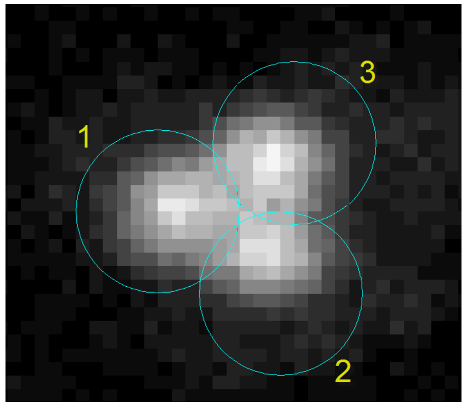

Figure 1: The "trimer" neon emission pattern from the FIM. The three lobes correspond to atomic sites on the emitter. The atomic sites are circled and enumerated to show the region which was subsequently analyzed

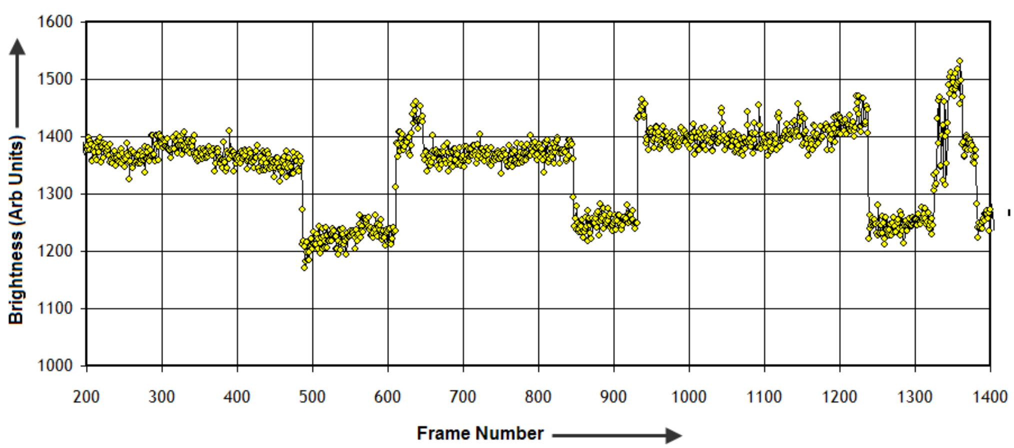

Figure 2: The average brightness of the indicated region is sometimes seen to fluctuate between two relatively stable states. In this particular case the analyzed region was site #2 (above), and the frame rate was 180 frames per second. The fluctuation represents about 15% change in emission.

[1] *Quest for High Brightness, Monochromatic Noble Gas Ion Source;* V. N. Tondare, J. Vac. Sci. Technol. A 23, 1498 (2005), DOI:10.1116/1.2101792.
[2] *Helium Ion Microscope: A New Tool for Nanoscale Microscopy and Metrology*; B. W. Ward, John A. Notte, and N. P. Economou, J. Vac. Sci. Technol. **B 24**, 2871 (2006), DOI:10.1116/1.2357967.
[3] The ORION™ HIM is a product of Carl Zeiss SMT Inc. (Peabody, MA); www.smt.zeiss.com.
[4] *Image Processing with ImageJ*; M.D. Abramoff, P.J. Magelhaes, S.J. Ram, Biophotonics International, **11** (7), pp. 36-42, (2004).