A CRT cathode as a multi-beam source for electron lithography

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The most commonly used electron beam lithography machines have either LaB_6 or Schottky emitters as electron sources. Schottky emitters yield the highest reduced brightness, up to several times 10^7 A/srm^{2}V, but cannot deliver the total currents needed for shaped beam lithography or cell projection lithography processes. In those machines, the LAB_6 emitter is the most popular, with a typical brightness of a few times 10^5 A/srm^{2}V. Most multi-beam lithography concepts proposed in the past or under development today have one emitter per beam[1], either a Schottky emitter, or a cold Field emitter[2,3],or a photocathode[4]. The challenges in such systems are to get sufficient beam-to-beam similarity and to keep the power per emitter sufficiently low that a large number of emitters can be employed. An alternative is to use a single emitter and split the emission into many sub-beams, either using a LaB_6 emitter[5] or a Schottky emitter[6,7]. The challenge to get beam-to-beam similarity now translates in a requirement to get sufficient uniformity of the current density at the emitter surface. A second challenge for a single emitter is to get sufficient total current.
We have investigated the potential of using a dispenser cathode in space charge limited emission mode of the type that are common in television tubes. The space charge limitation guarantees stable and uniform emission even if there are small work function variations or bumps and depressions on the surface[8]. The I-cathodes were purchased from L.G. Philips Blackburn and mounted in a system with an extractor, a micro machined silicon aperture array and a fluorescent screen, see figure 1. The reduced brightness can be calculated from the beam potential, current per beam, the size of the apertures and the half angle in the beam. The latter can be deduced from the size of the spots on the YAG screen because their size is substantially larger than the diameter of the apertures. Figure 2 shows the typical image on the YAG screen. Figure 3 shows the brightness as a function of the emission current density. These measurements are performed at a typical angular current density of 0.5-1.0 A/sr. Note from figure 3 that the brightness drops if the emission current density surpasses a threshold value, a value that depends on the temperature. This effect occurs if the emitter leaves the space charge limited regime. Brightness values of 10^6 A/srm^{2}V can be reached with these standard cathodes, while there are reports in literature that cathodes yielding 10 times the emission current density have been in operation[9].

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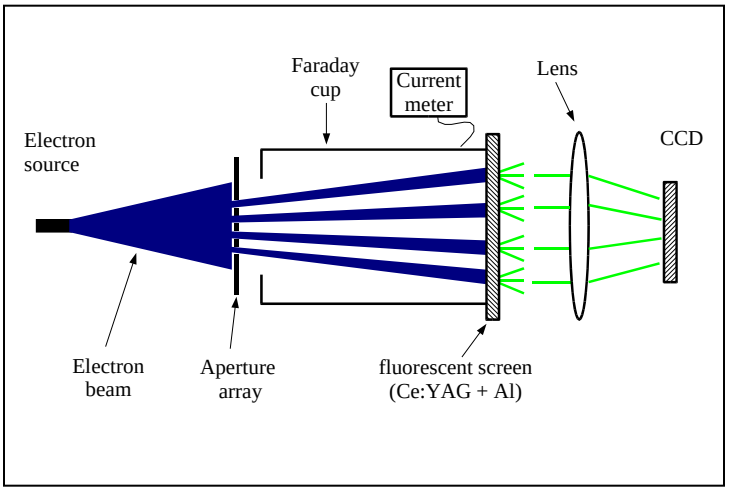

Figure 1: Schematic experimental set-up to split the emission from the CRT dispenser diode into 100 sub beams and measure the brightness of the individual beamlets.

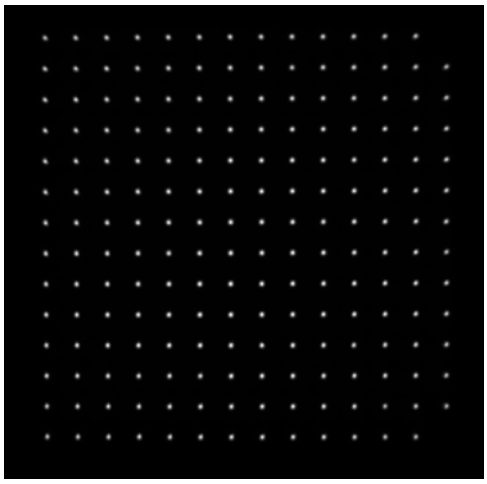

Figure 2: Image on the CCD camera

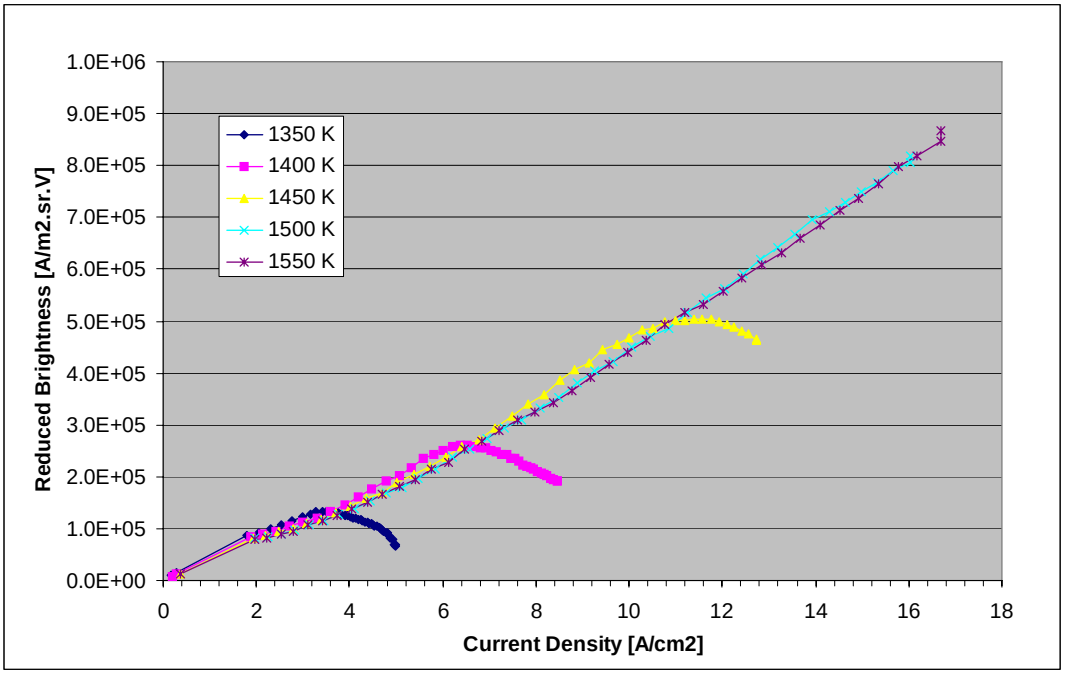

Figure 3: Measured brightness of the individual beamlets from a commercial CRT cathode for different temperatures of the cathode.