# Spatially resolved and quantifiable field emission measurements using a CMOS imaging sensor

A. Schels, S. Edler, F. Herdl, W. Hansch
*Institute of Physics, Universität der Bundeswehr München, 85577 Neubiberg, Germany*
*andreas.schels@ketek.net*

M. Bachmann, D. Ritter, F. Düsberg, A. Pahlke
*KETEK GmbH, 81737 Munich, Germany*

Field emission (FE) cathodes are promising for many applications. Their commercial applicability is mainly limited by their lifetime, especially at high current densities. In order to distribute the total current load over a certain area, field emission arrays (FEAs) are often used. However, homogeneous current distribution is crucial here, wherefore spatially resolved FE measurements play a decisive factor in the further development of existing field emitter concepts. Besides costly, non-integral and time-consuming measurement methods,[1] luminescence of phosphor screens is the most common way to get an overview of the current distribution. However, their resolution, luminescence and the evaporation of the phosphorus at high currents limits their applicability.[1]

In this contribution, we use a commercially available and low-cost CMOS camera for spatially resolved and fully quantifiable current distribution measurements. The measured samples are silicon FEAs whose fabrication process is similar to that recently published by Edler et al.[2] The whole measurement setup, including the stack of FEA, insulation layer and CMOS camera, as well as a regulation circuit for constant current measurements, is shown in Fig. 1. By combining different exposure times, oversaturated and underexposed pixels can be extrapolated, resulting in a congruence of measured integral current and image brightness, as shown in Fig. 2(a). The sensitivity, which is calculated from the brightness-to-current ratio, remains unchanged over 10 full measurement cycles. In combination with a point detection algorithm (see Fig. 2(b)) the method allows quantified analysis of all individual emission spots participating during integral operation, exemplarily shown in Fig. 3, with measurable single spot currents ranging from a few nanoamperes to one microampere per tip. The measurements will be used to investigate the emission behavior of individual tips during integral operation of differently doped samples, thus providing unprecedented insight into the saturation behavior of p-doped silicon FEAs.

---

[1] P. Serbun, V. Porshyn, G. Müller, and D. Lützenkirchen-Hecht, Rev. Sci. Instrum. **91**, 083906 (2020).
[2] S. Edler *et al.*, J. Vac. Sci. Technol. B **39**, 013205 (2021).

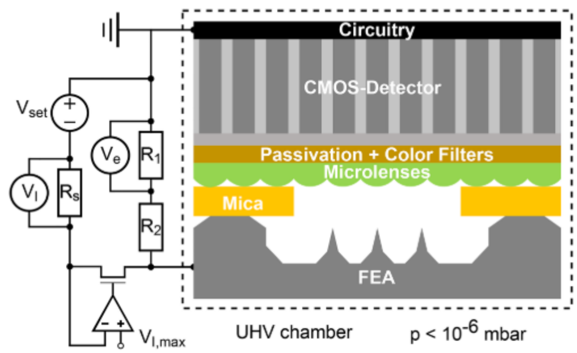


*Figure 1: Schematic measurement setup consisting of the FEA, a mica sheet for electric insulation and the CMOS sensor with his passivation layer, color filters and microlenses. The setup contains a regulation circuit for constant current and maximum current limited measurements. All measurements are performed at a pressure below 10-6 mbar.*

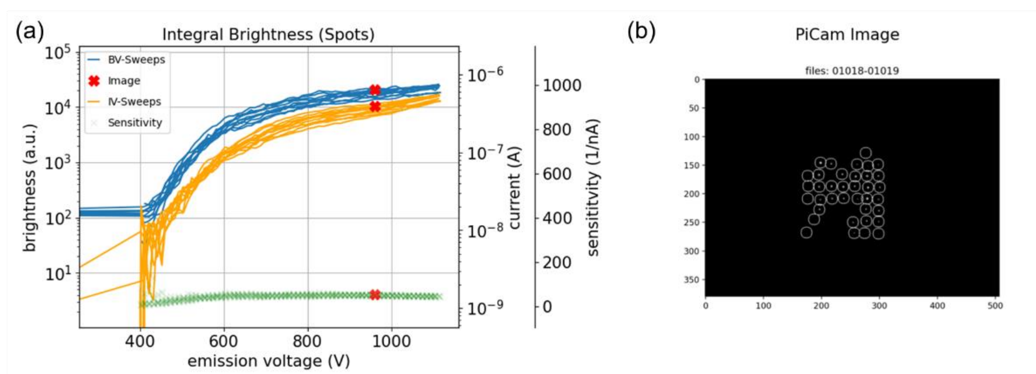


*Figure 2: (a) Measurement of a p-doped silicon FEA showing 10 consecutive current-voltage sweeps (orange), as well as the corresponding brightness-voltage characteristics (blue) and the calculated sensitivity of the sensor for each sweep (green). The red crosses indicate the measurement point corresponding to the recorded image shown in (b). The white circles in the depicted image are the result of the automatic point detection algorithm used for analyzing individual spot currents.*

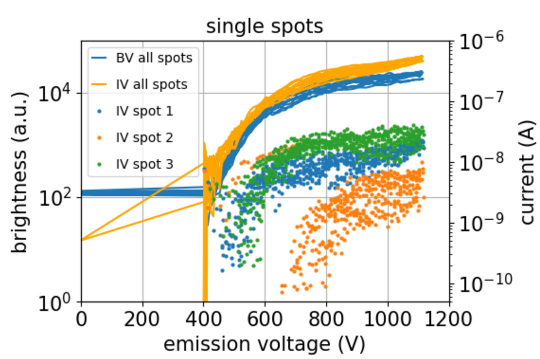


*Figure 3: Exemplary single spot characteristics for 3 randomly selected emission spots calculated by using the sensitivity shown in Fig. 2.*