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PRELIMINARY STUDIES OF BEAM-INDUCED FLUORESCENCE AND STATUS OF THE BEAM-CURRENT UPGRADE OF THE ELECTRON-COOLER TEST-BENCH AT HIM*

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Abstract

First wavelength-resolved studies of the beam-induced fluorescence (BIF) have been made at the cooler teststand. Its upgrade to 30 kV has been completed, which will allow operation at 1 Ampere beam current. Operation with the upgraded parameters is imminent and options for further experiments will be discussed.

ELECTRON COOLER TEST BENCH AT HIM

A electron cooler test bench including components from TSL (Uppsala) and BINP (Novosibirsk) has been put into operation at Helmholtz-Institut Mainz (HIM) and is currently working at $U_{\text{Source}} = 17\,\text{kV}$, $U_{\text{Collector}} = 3\,\text{kV}$ and $I = 0.55\,\text{A}$ (figure 1). From the source to the collector, the beam is immersed in a longitudinal magnetic field. So far, the main investigations were related to the relative number of backstreaming electrons from the collector. The results indicate that the flow of electrons towards ground potential in a fully magnetized high energy cooler is very low. This is mainly due to the implementation of the Wien filter, which was already installed in the COSY cooler developed by BINP [1]. A detailed description of our apparatus and the results achieved can be found in [2]. The present study aims at optical detection as a method of obtaining information about the electron beam intensity distribution.

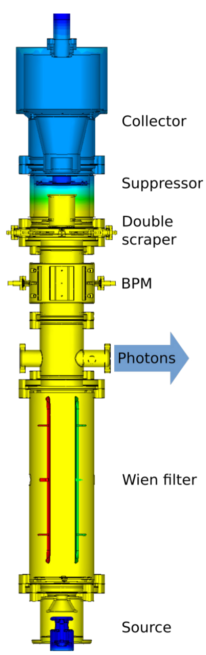

Figure 1: Schematic sketch of the electron cooler at HIM.

OPTICAL BEAM DIAGNOSTICS

We have observed that even under UHV conditions (pressure when electron beam is on: $< 2\cdot10^{-10}$mbar) photons are emitted from the apparatus. In order to find out if they are related to the beam or to other background sources (e.g. light emitted from the collector), we have performed several test experiments.

At the windowed flange just above the Wien filter (position marked “Photons” in figure 1), photons emitted from the beam pipe can be observed. These were measured by an optical setup consisting of a remotely controllable lens and slit in front of a cooled photomultiplier tube (PMT, $T_{\text{PMT}} = -20\,°\text{C}$). The distance of the lens from the beam orbit is varied with the intention to find a distance where a sharp image is obtained. The definition of the image was investigated in one dimension by moving the slit laterally in front of the PMT (figure 2).

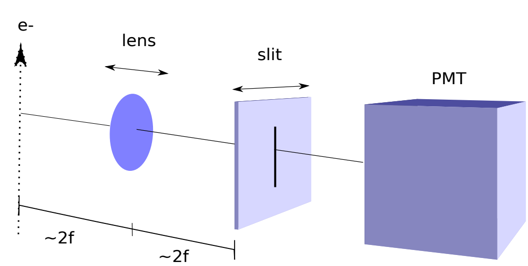

Figure 2: Schematic of the optical setup.

A series of bandpass filters with different center wavelengths (400 nm, 450 nm, 500 nm, 550 nm, 600 nm, 650 nm, 700 nm) and a FWHM bandwidth of $\lambda_{\text{FWHM}} = 50\,\text{nm}$ were added behind slit in order to obtain wavelength-resolved measurements. Transmission of the sapphire viewport (79-84%) and the quantum efficiency of the PMT (15-30%) were taken into consideration. This

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setup allowed us to scan the images width and the depth of field of the signal for a beam current of $I = 0.55$ A, as shown in figure 3. A background signal measured without an electron beam was subtracted. The infrared background caused by the dispenser cathode (BaW) behaves according to planck's law (figure 4) and becomes dominant above $\lambda_{\mathrm{CWL}} = 550$ nm (figure 5). We have also determined the number of photons as a function of the beam current, which increases overproportionally (figure 6). A sharp image could not be observed, which is presumably due to reflections from the walls of the observation chamber.

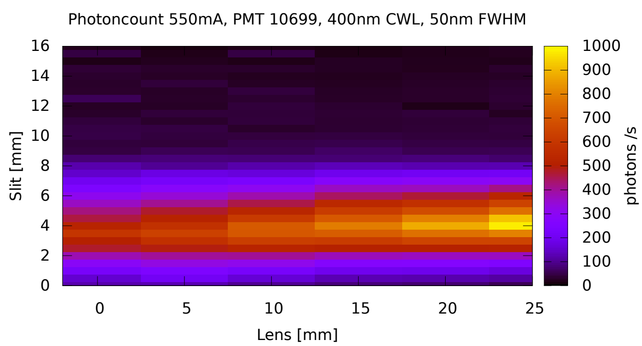

Figure 3: Photons per second for different lens and slit positions at a beam current of $I = 0.55$ A at $\lambda_{\mathrm{CWL}} = 400$ nm; a background measurement with no electron beam has been subtracted.

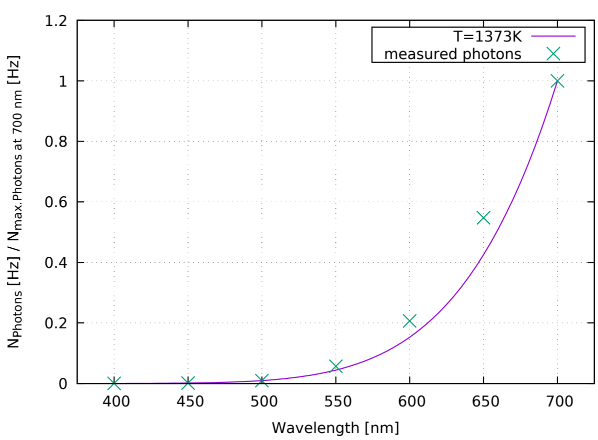

Figure 4: Background measurements compared to the black body radiation of the cathode at $T = 1373$ K.

These measurements do not contradict the preliminary hypothesis of fluorescence caused by ions (e.g. H_2^+) trapped in the electron beam potential [4] and suggest wavelength-resolved measurements at higher resolution with a higher beam current.

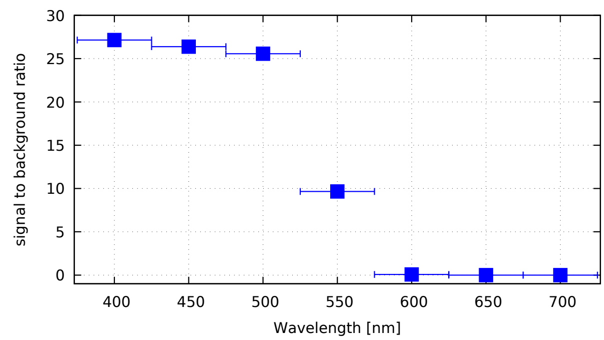

Figure 5: Signal to noise ratio for the measured wavelengths.

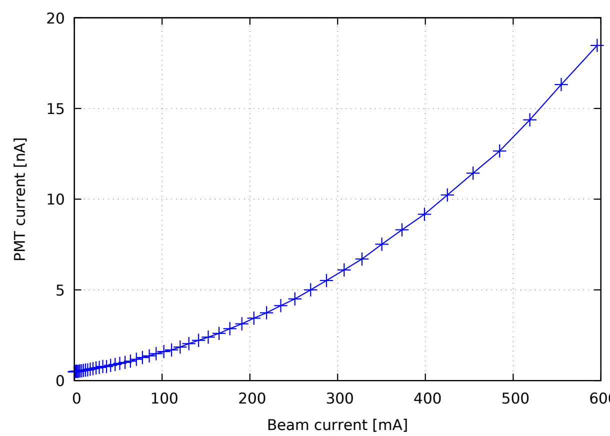

Figure 6: Photon signal for fixed lens and slit positions at different beam currents.

UPGRADE OF THE TEST BENCH

In order to increase the beam current to $I = 1$ A, the acceleration voltage needs to be raised to $U_{\mathrm{Source}} = 30$ kV, which is why the test bench was fitted with larger electrical insulators. In first measurements, for solenoid fields at the source of $B_{\mathrm{Solenoid}} \geq 60$ mT, it showed a tendency for gas-discharges, likely due to trapping, which requires avoidance of potential minima in regions A and B as shown in figure 7 [3].

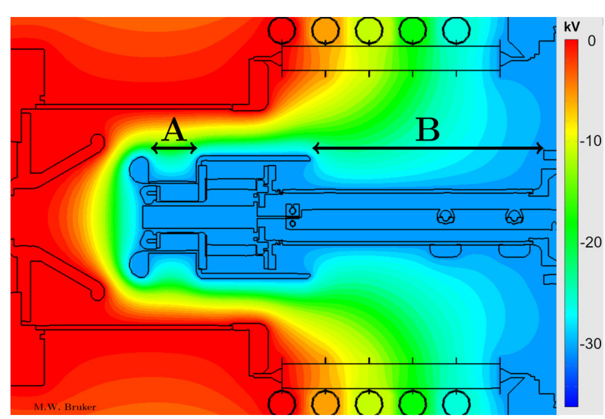

Figure 7: Potential map of the 17 kV source with regions A and B.

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The source was altered with parts manufactured in-house (except the ceramics for the HV insulators) to allow an increase in HV and to shrink region B and avoid the narrowing in region A (figure 8).

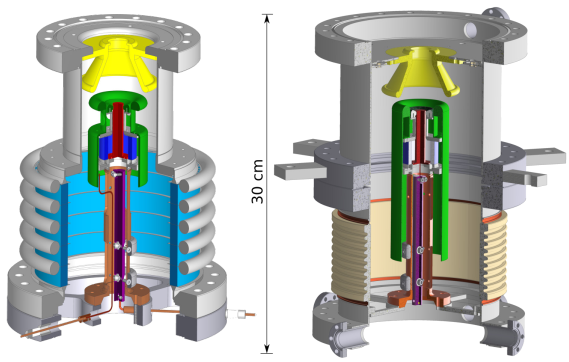

Figure 8: CAD models of the old (left) and new (right) source design.

After assembly in the HIM cleanroom (figure 9) the HV tests were executed successfully and the redesign proved to be robust against gas-discharges up to $B_{\mathrm{Solenoid}} = 90\,\mathrm{mT}$, with additional elongation (through addition of a second, identical coil (figure 10)) of the solenoid field against the beam direction up to the, with the given magnets, highest achievable field $B_{\mathrm{Solenoid}} = 115\,\mathrm{mT}$.

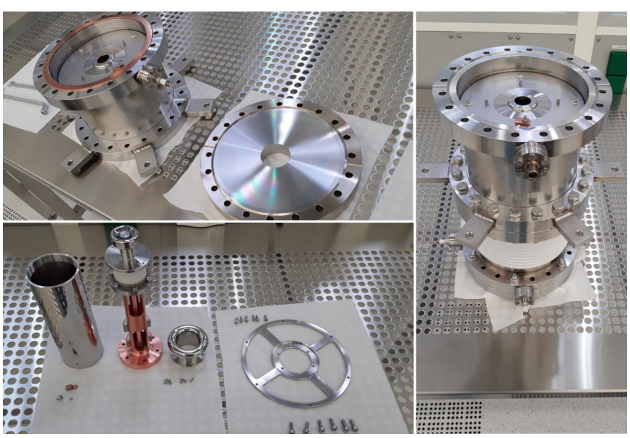

Figure 9: Different stages of assembly of the redesigned source in the HIM cleanroom.

In addition to the endeavor to increase the beam current, the observation chamber has been modified to decrease infrared background, i.e. it has been blackened with a graphite coating and a reflective screen mounting system was removed. After the HV tests of the source, the whole test bench has been assembled, evacuated and baked out. Improved HV- and radiation protection measures are being implemented as of the publication of this paper.

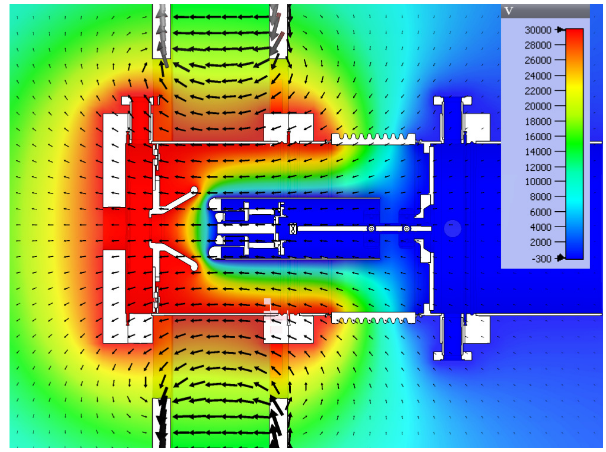

Figure 10: Potential map with magnetic field lines of the 30 kV source with the longer solenoid field.

CONCLUSION

Wavelength-resolved measurements of beam induced fluorescence (BIF) have been made via a cooled photomultiplier tube. These measurements show an overproportional correlation with the beam current and support the preliminary hypothesis of fluorescence caused by ions trapped in the beam potential. Measures to increase the beam current and reduce the infrared background caused by the hot dispenser cathode have been taken. Operation of the upgraded test bench is imminent. A cooled CCD camera for faster and more detailed measurements will be acquired in the near future and a higher resolution spectral analysis of the photon signal is in the planning stages.

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