# Improving detection efficiency using polycapillary optics for broadband, ultrahigh resolution spectroscopy of particle induced X-rays with TES microcalorimeter arrays


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*Measuring delicate pieces of art in order to ascertain their authenticity can be nontrivial and must be non-destructive [1]. One such method is Particle Induced X-ray Emission (PIXE) spectroscopy, which has been shown to detect trace elements in pigments [2]. Beam irradiation can be used non-destructively, when the beam time is kept to a minimum, and the motivation for this study is to reduce the beam time while keeping the number of detected counts the same. Two different methods are shown here that improve the detection [3], while still being able to measure delicate objects in air. Changing the gas through which the X-rays travel as shown in Fig. 1 and increasing the solid angle of the detector by using focusing polycapillary optics. A transition-edge sensor (TES) in conjunction with helium atmosphere for the X-ray focusing polycapillary lens detects trace impurities non-destructively in air.*


## The problem

Measuring delicate objects, such as museum artifacts needs to be done non-destructively and in atmospheric pressure [1]. However, transmission of low-energy X-rays to the TES detector proves to be nontrivial, due to other limitations. Moving the bulky cooling platform [4] closer to the sample increases the solid angle of the detector, while sacrificing low-energy transmission due to need of increased filtering for protons. Here we propose two different and concurrently realizable solutions to increase the transmission of X-rays and the solid angle of the detector. Adding a focusing polycapillary lens to increase the solid angle and using helium atmosphere to reduce transmission losses in the distance from the sample to the detector.

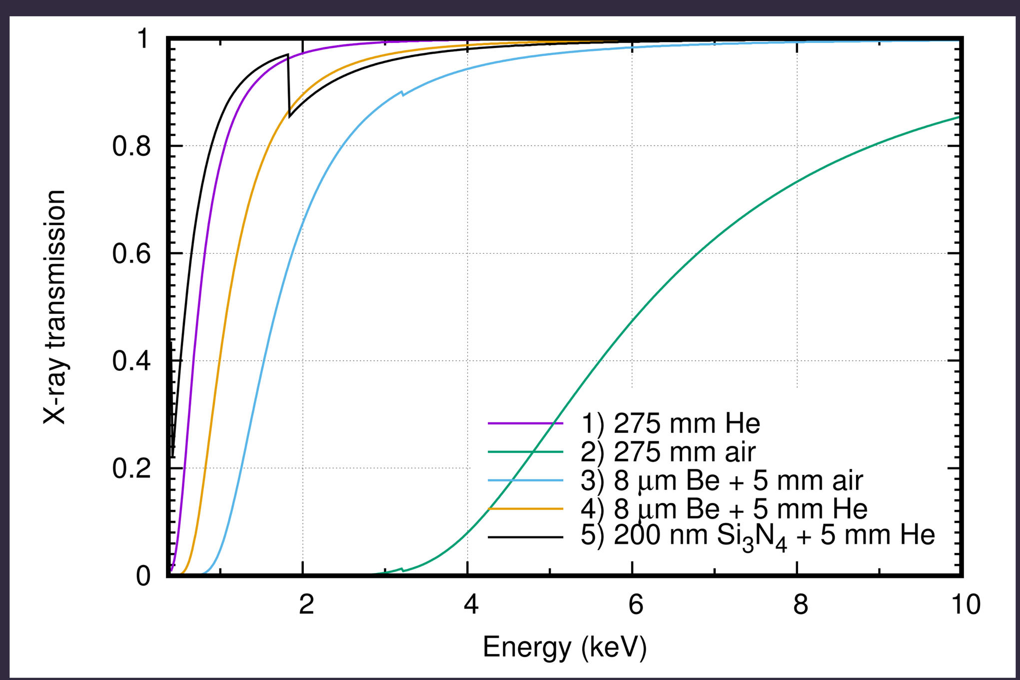


Figure 1: Transmission of X-rays for five different scenarios. It is clearly seen that the measurements in air is simply not feasible. Transmission losses due to the polycapillary lens are not taken into account in this plot.

## The results

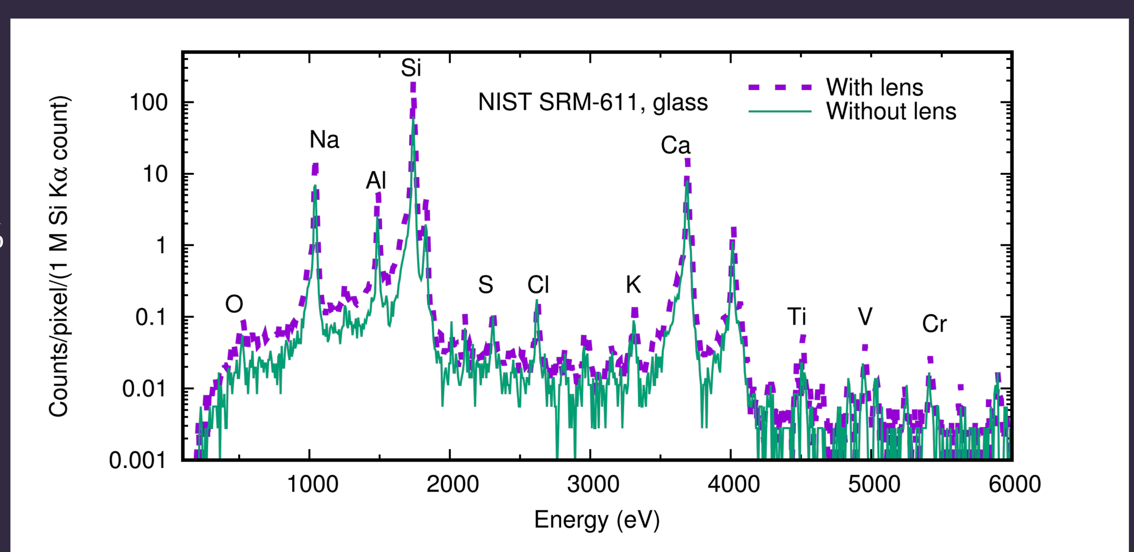


Figure 2: Measured X-ray spectra of NIST srm611 calibration sample with 72% SiO2, 14% Na2O, 12% CaO, 2% Al2O3 nominal matrix composition. 8 eV bin width is used for clarity and scaling is done with intensity per pixel per million counts in Si K$\alpha$.

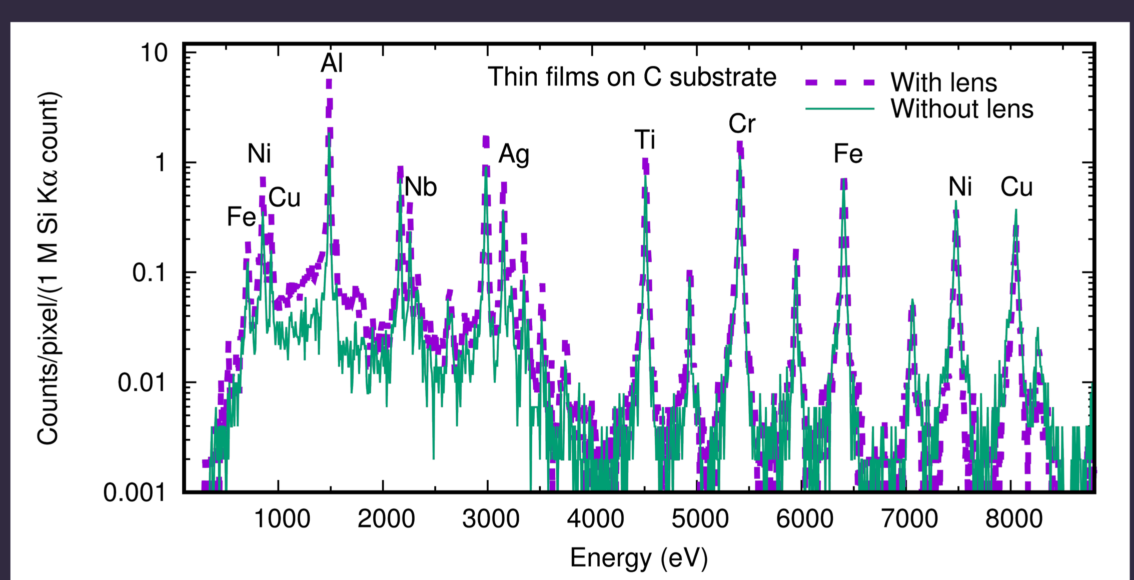


Figure 3: Measured X-ray spectra of a calibration sample with Al, Nb, Ag, Ti, Cr, Fe, Ni, Cu thin films on top of C substrate. Intensity scaled to counts per pixel per million counts in Si Kalpha peak area measured from the beam exit window. 8 eV bin width is used for clarity and scaling is done with intensity per pixel per million counts in Si K$\alpha$.

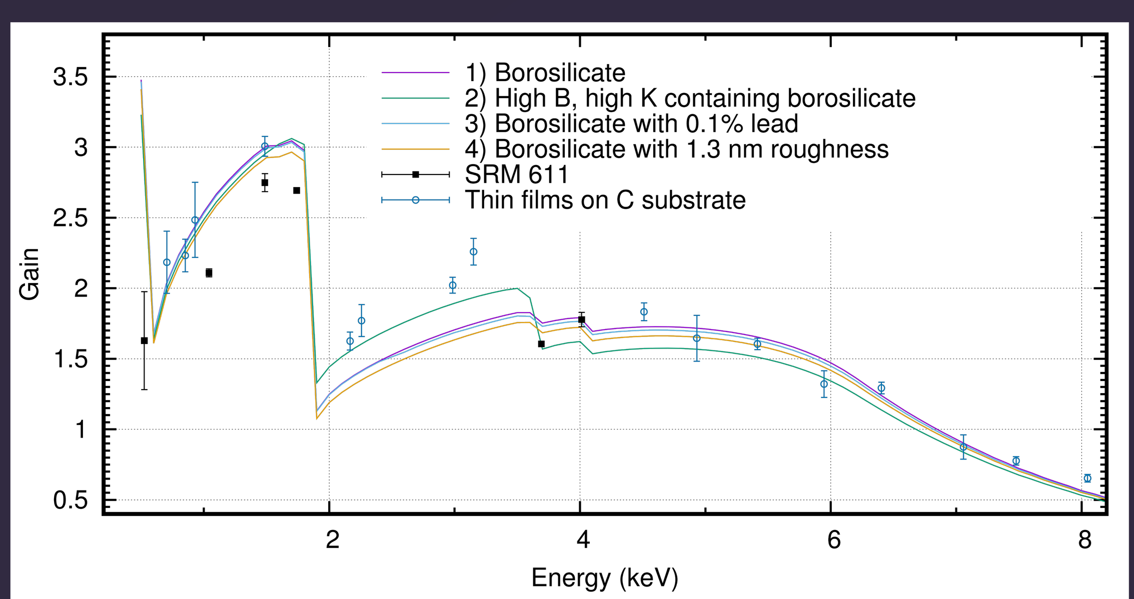


Figure 4: Increase in Gain compared with the polycapillary lens, unity means same transmission with and without the polycapillary lens. Measured and calculated values shown where 1), 3) and 4) have the composition: 81% $SiO_2$, 13% $B_2O_3$, 2% $Al_2O_3$, 2% $Ca_2O$, 2% $K_2O$. Composition for 2) is 65% $SiO_2$, 25% $B_2O_3$, 2% $Ca_2O$, 8% $K_2O_3$ for the calculations.

## The setup

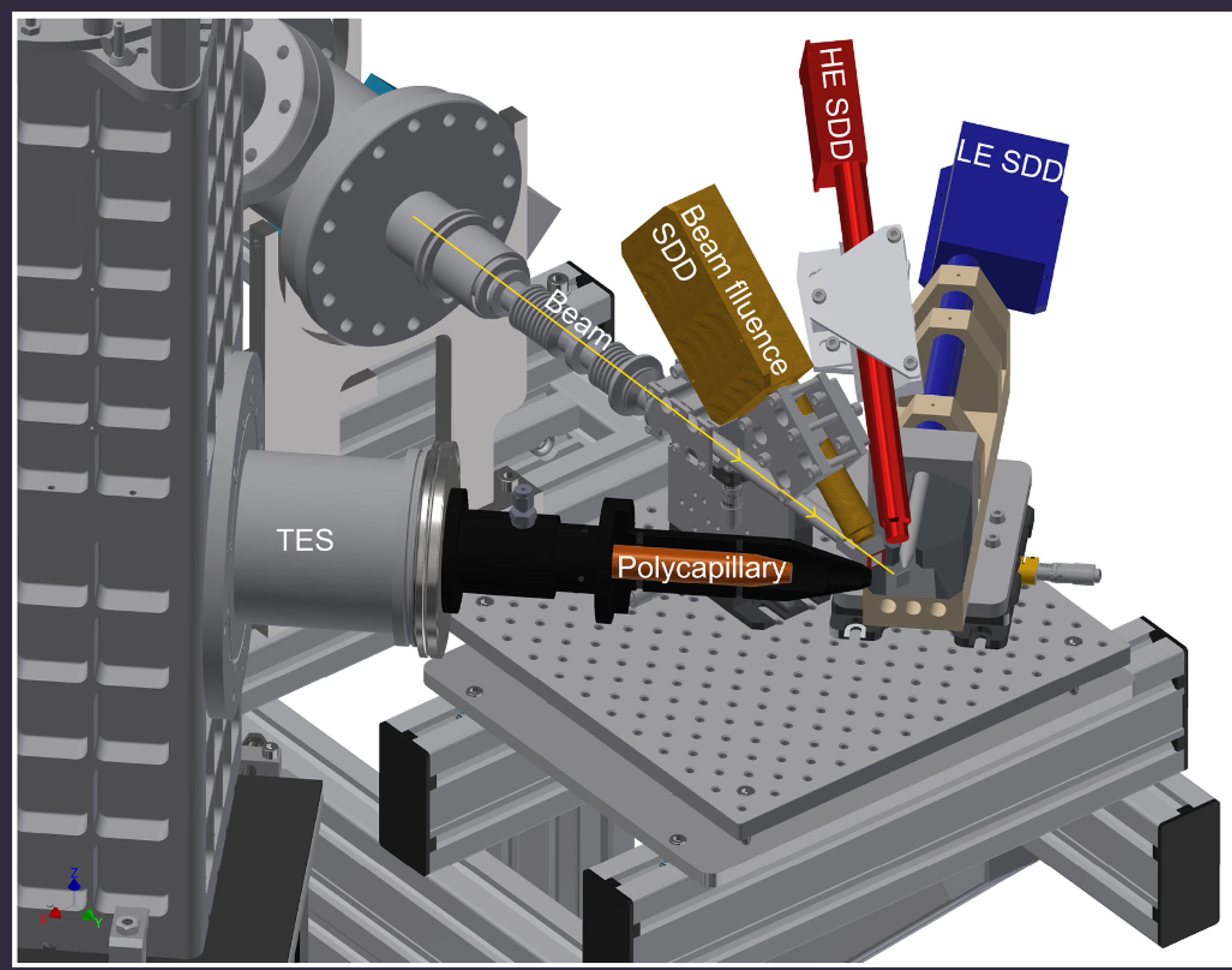


Figure 5: Schematic of the detector setup

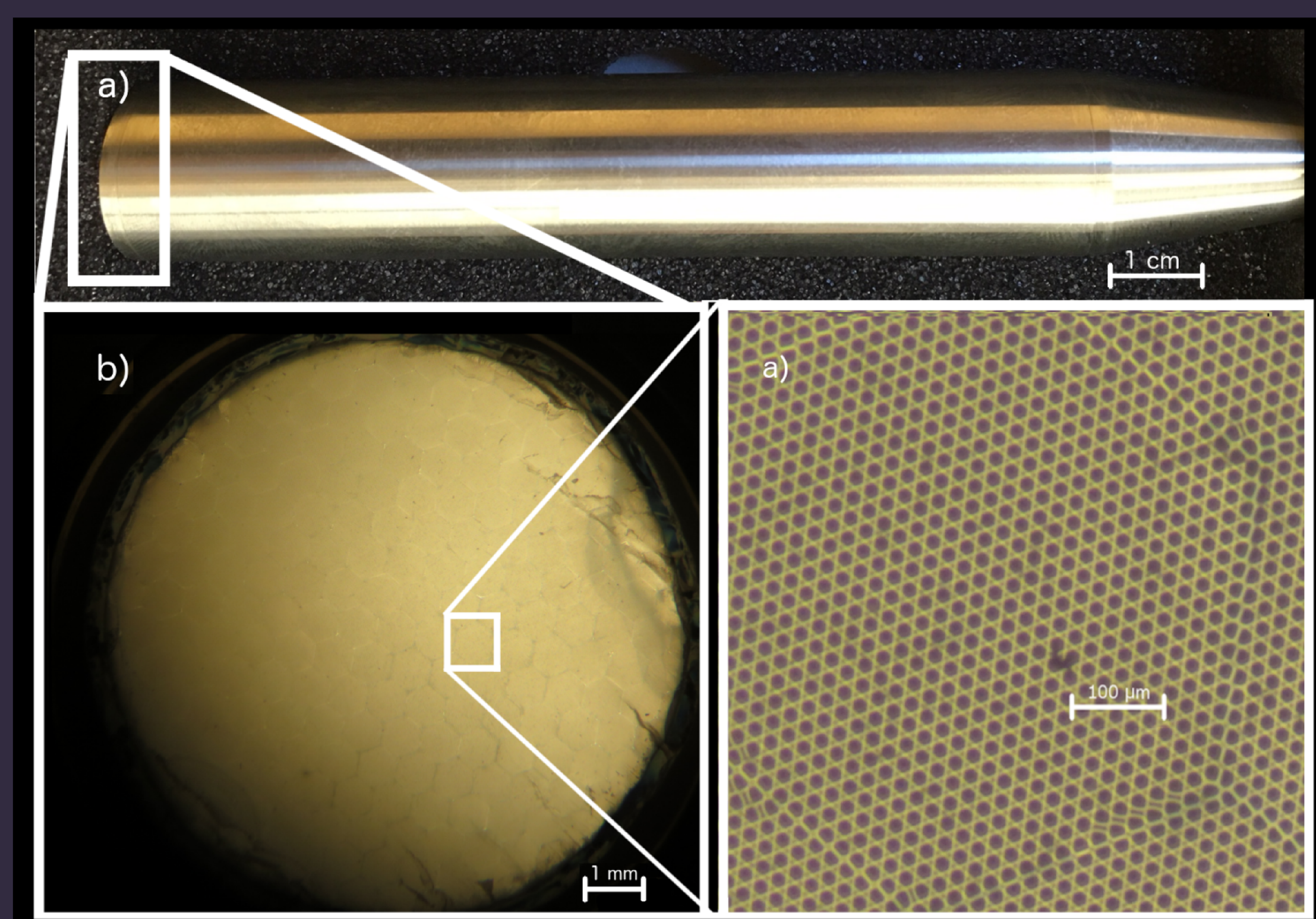


Figure 6: Zoomed images of the polycapillary lens

## The conclusions

Improvements in detection efficiency were gained by adding a polycapillary lens with helium atmosphere between the sample and the TES detector. The polycapillary lens also enabled the detection of oxygen or nitrogen as the lightest element, when measuring in vacuum. Previously the lightest element has been aluminium. Theoretical calculations agree with the experimental data.

## References:


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