Spectral sensitivity of ICCD cameras in IR range

Experimental setup

To test the sensitivity of several image intensifiers (MCPs) in the IR range, we used first two kinds of infrared LEDs with peak spectral emissions at 880 and 950 nm. These LEDs were successively coupled to the input of a spectrometer which allowed us to select the wavelength of interest. The radiation at the output of the spectrometer was then analyzed by an ICCD camera. The corresponding images were processed with our 4Spec software which is specifically designed and appropriate for intensity measurements. Because all pictures were not taken with the same integration times and number of frames, we had first to normalize them, i.e. to correct them by applying the appropriate multiplication factor. In our case, the goal was to draw the intensity distribution of the radiation at a defined wavelength and to calculate its value. As shown in figure 1, this can easily be done with 4Spec by defining curve bands on the image and then by calculating the integral of the drawn distribution. The same process was used for several wavelengths in order to obtain curves showing the radiation intensity as a function of wavelength.

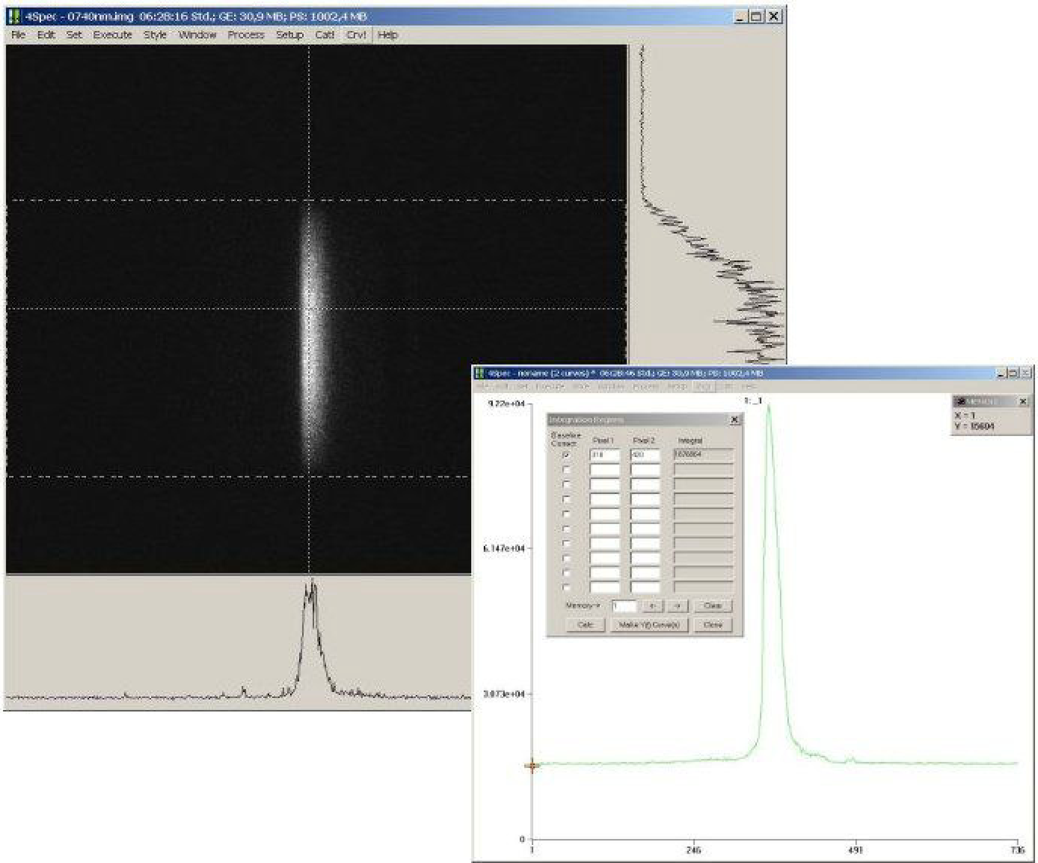

Figure 1. Image processing and analysis with 4Spec software

The next step consisted in taking the spectral emission curves of the LEDs into account in order to get the real sensitivity of the MCPs. This could be done by dividing our measured values by the exact emitted intensity of the LEDs for each wavelength. For low and high wavelengths (<700nm and >1000nm), the ICCD camera detected scattered light whose intensity had to be subtracted from our measurements.
Furthermore it was noticed that some unwanted reflections in the spectrometer had an significant influence in our results. That´s why some additional diaphragms were inserted inside the spectrometer in order to minimize these reflections.

However the results for high wavelengths were only best guess assumptions because of the low intensity emission characteristics of the LEDs used. To check and improve the accuracy of these results, some further measurements were performed by using a tungsten ribbon lamp which behaves like a black body. This lamp possesses a much wider spectral distribution than the LEDs and is consequently more appropriate for our sensitivity measurements in the IR range. The same experimental setup was used but two red filters were inserted between the lamp and the spectrometer input in order to minimize the spectrometer´s second order effect. Finally, the sensitivity curves obtained matched the extrapolated previous curves very well and confirmed the legitimacy of our assumptions. Figure 2 shows the measured MCP sensitivity by using the tungsten ribbon lamp and the extrapolated curve for high wavelengths which gets rid of the light scatter effect of the spectrometer.

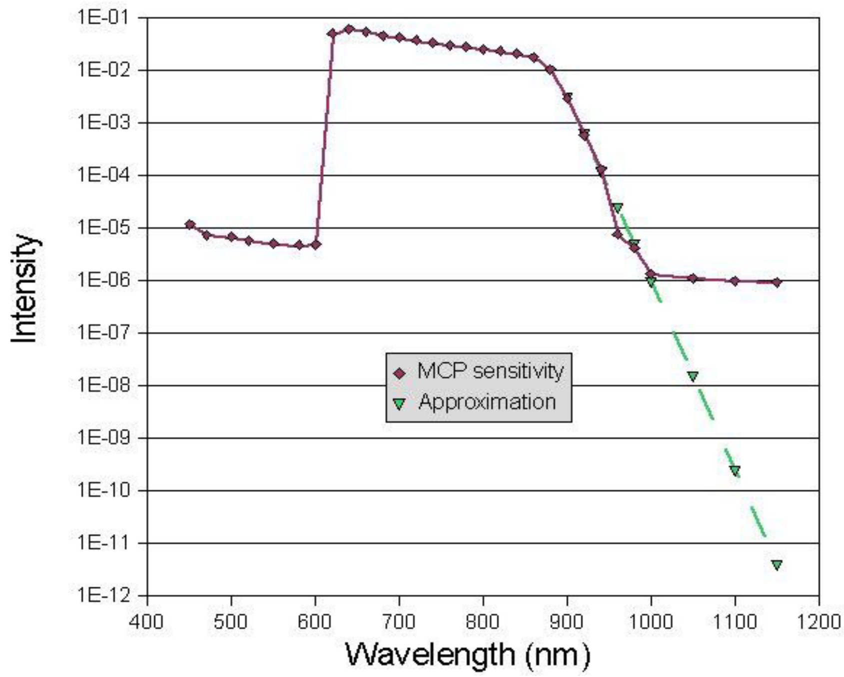

Figure 2. Spectral sensitivity of a typical image intensifier and extrapolation of the curve in the IR range to overcome the light scatter effect inherent to the spectrometer.

Results

Three types of MCPs were tested by using the protocol described in the previous section. All our measurements were made twice using the two LEDs (880 and 950nm) and the corresponding results were found to be always very similar. Due to the uncertainty on the true spectral distribution of the LEDs for wavelengths above 1000nm, some of our measured intensities had to be extrapolated for high wavelengths. Figure 3 shows the measured sensitivities of the three types of MCPs which have been normalized by using the existing sensitivity charts given by the manufacturers. We see for instance that we can expect a sensitivity of about 10µA/W (QE≈0.001%) at 1000nm and 20nA/W (QE≈$2.25x10^{-6}$%) at 1100 nm for an DEP XX1450YP MCP type.

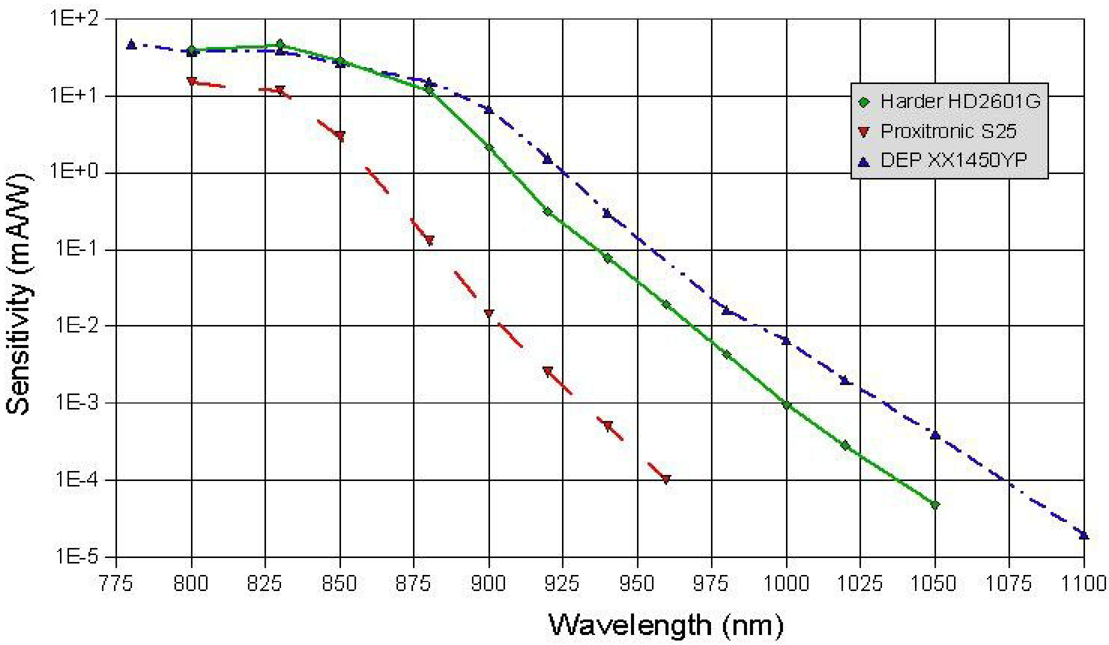

Figure 3. Extended sensitivities of three different types of MCPs.