

Non-linearities in photodiode response at high intensities

C. Tarrio, R. E. Vest, S. Kulin, and S. Grantham

*National Institute of Standards and Technology
Electron and Optical Physics Division
Gaithersburg MD 20899 USA,*

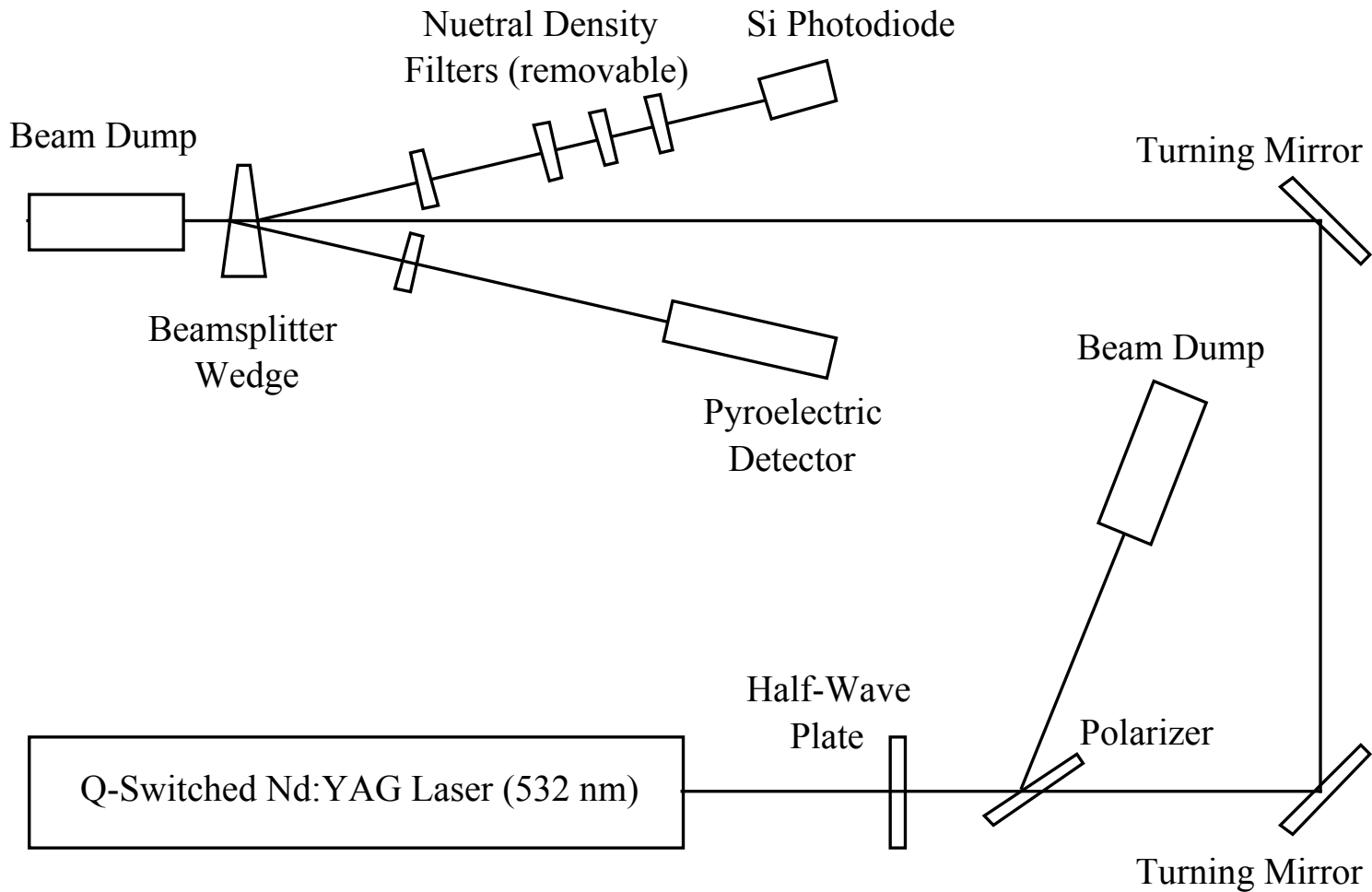
Metrology poster #45

Although EUV sources are pulsed with very high instantaneous intensities, the detectors used to characterize the sources are calibrated at low CW powers. To predict the behavior under these conditions we have done the following:

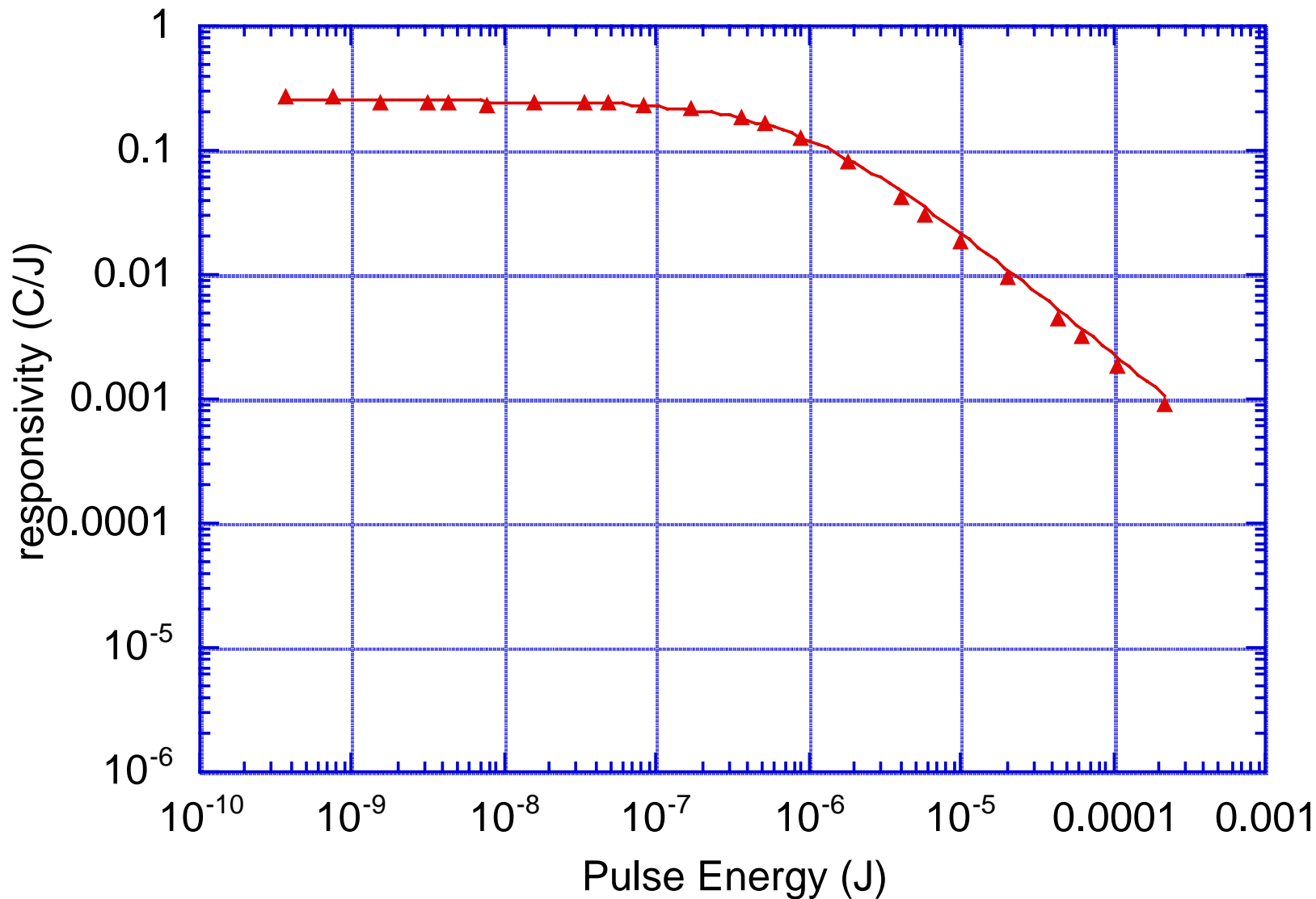
- 1) Calibration at varying intensities using 532 nm pulsed radiation (similar penetration depth to 13 nm radiation in silicon)
- 2) Calibration at varying intensities using 13 nm CW radiation
- 3) Calibration at varying intensities using 532 nm CW radiation

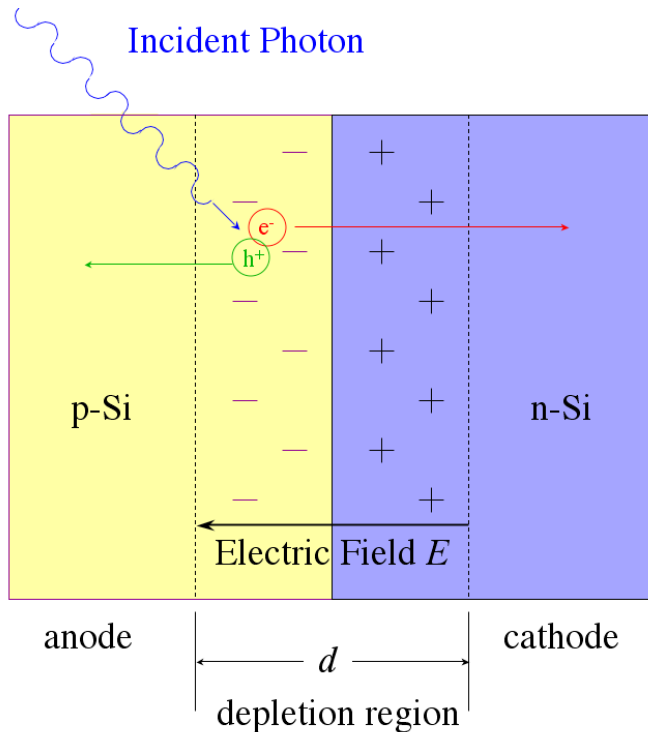
With these three measurements, we can quantitatively predict the behavior at 13 nm with high-intensity pulsed radiation.

Pulsed 532 nm measurements



Pulsed 532 nm results





Photogenerated carriers may recombine with thermally generated minority carriers, reducing the measured responsivity. Since the concentration of photogenerated carriers increases with intensity, the losses are greater for higher pulse energies.

Non-Linear Calibration

Two Constants are Required

$$\eta(E_p) = \frac{1}{\alpha + \beta E_p}$$

The first constant characterizes the low-power limit:

$$\eta(E_p \rightarrow 0) = \frac{1}{\alpha} = \text{constant}$$

The second characterizes the saturation behavior:

$$\eta(E_p \rightarrow \infty) = \frac{1}{\beta E_p}$$

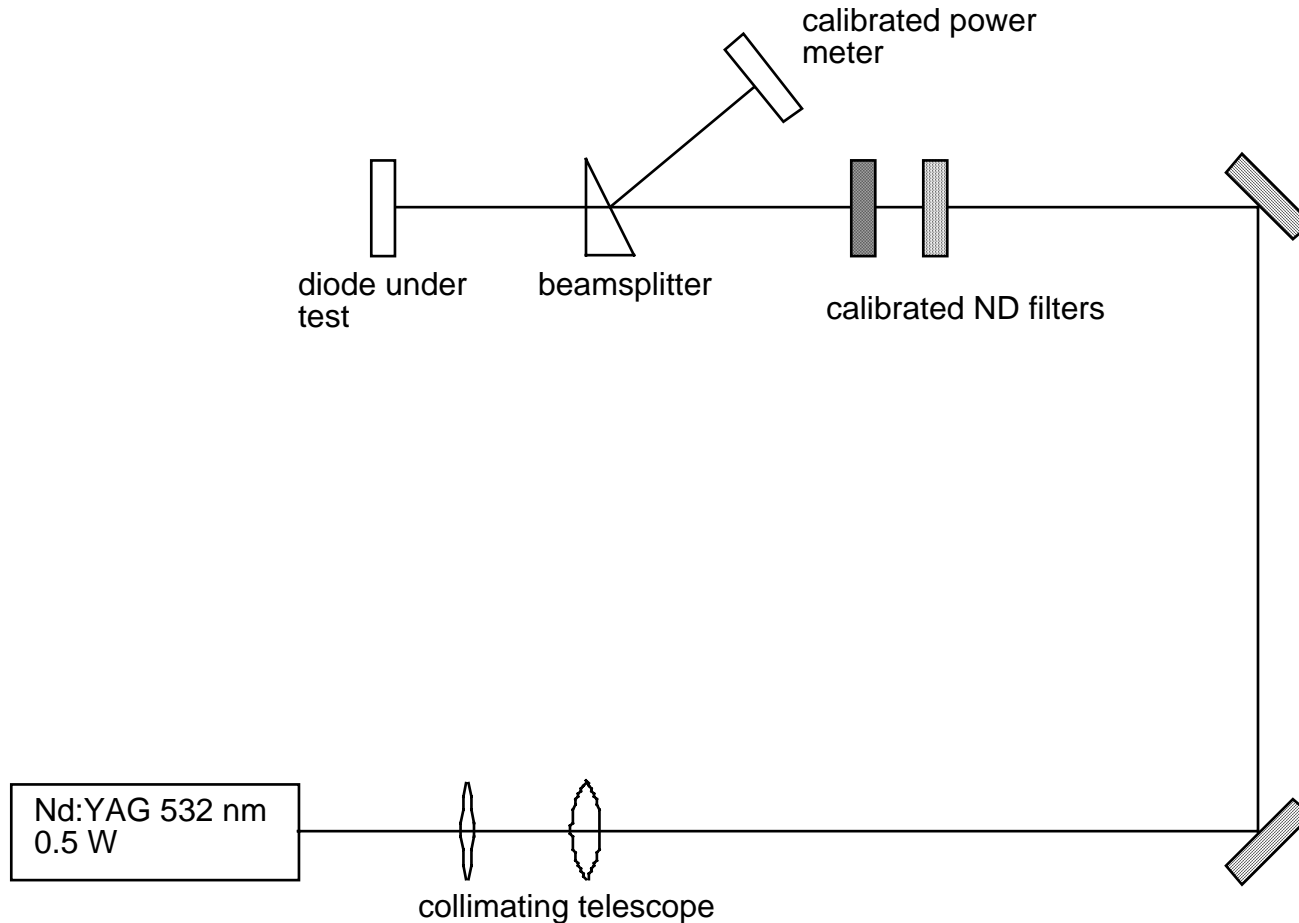
The response from the photodiode in saturation is constant:

$$R(E_p \rightarrow \infty) = \frac{1}{\beta E_p} E_p = \frac{1}{\beta} = \text{constant}$$

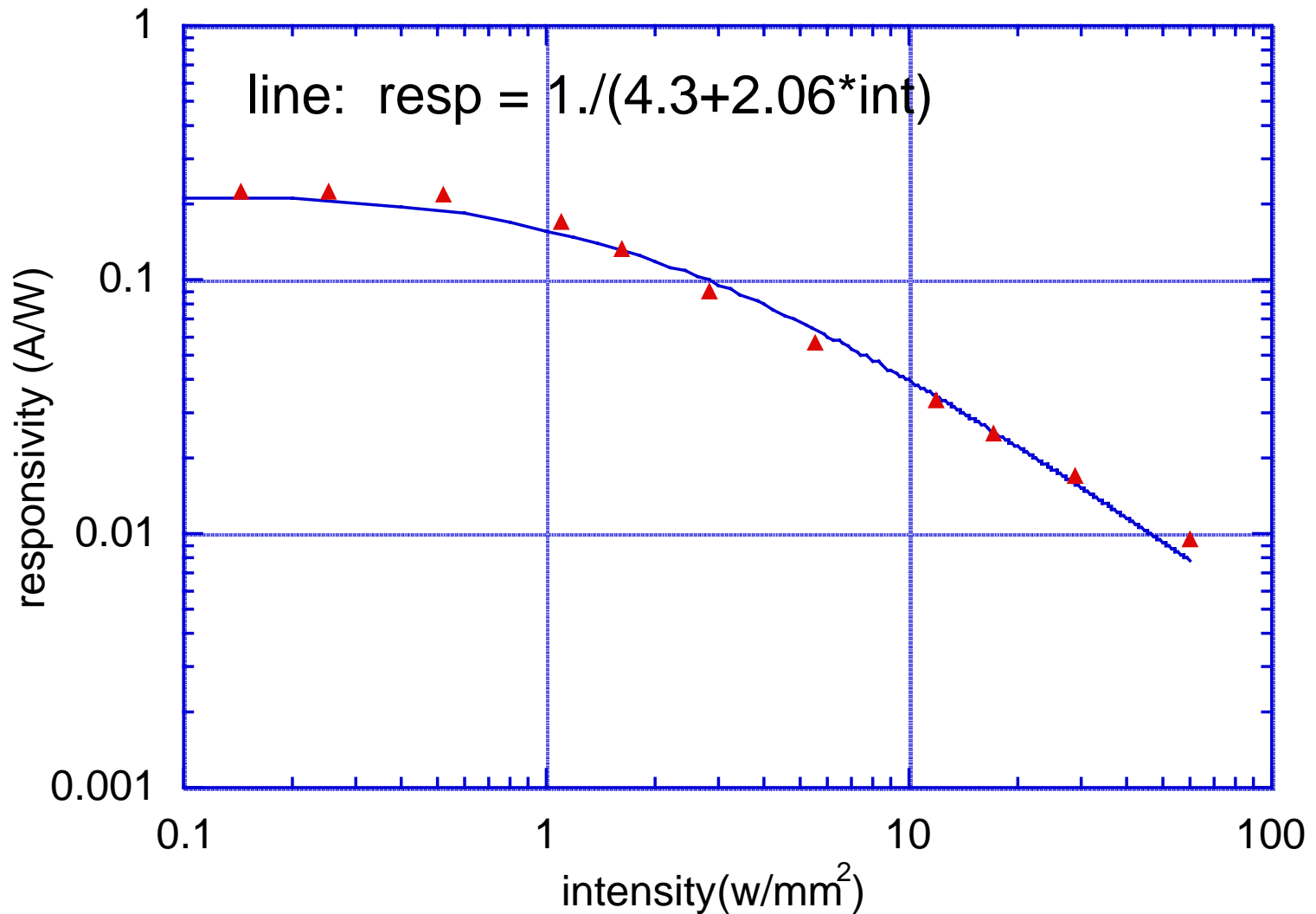
The responsivity at $E_p=0$ is the low-power CW responsivity:

$$\eta(0) = \frac{1}{\alpha} = \eta_{cw}$$

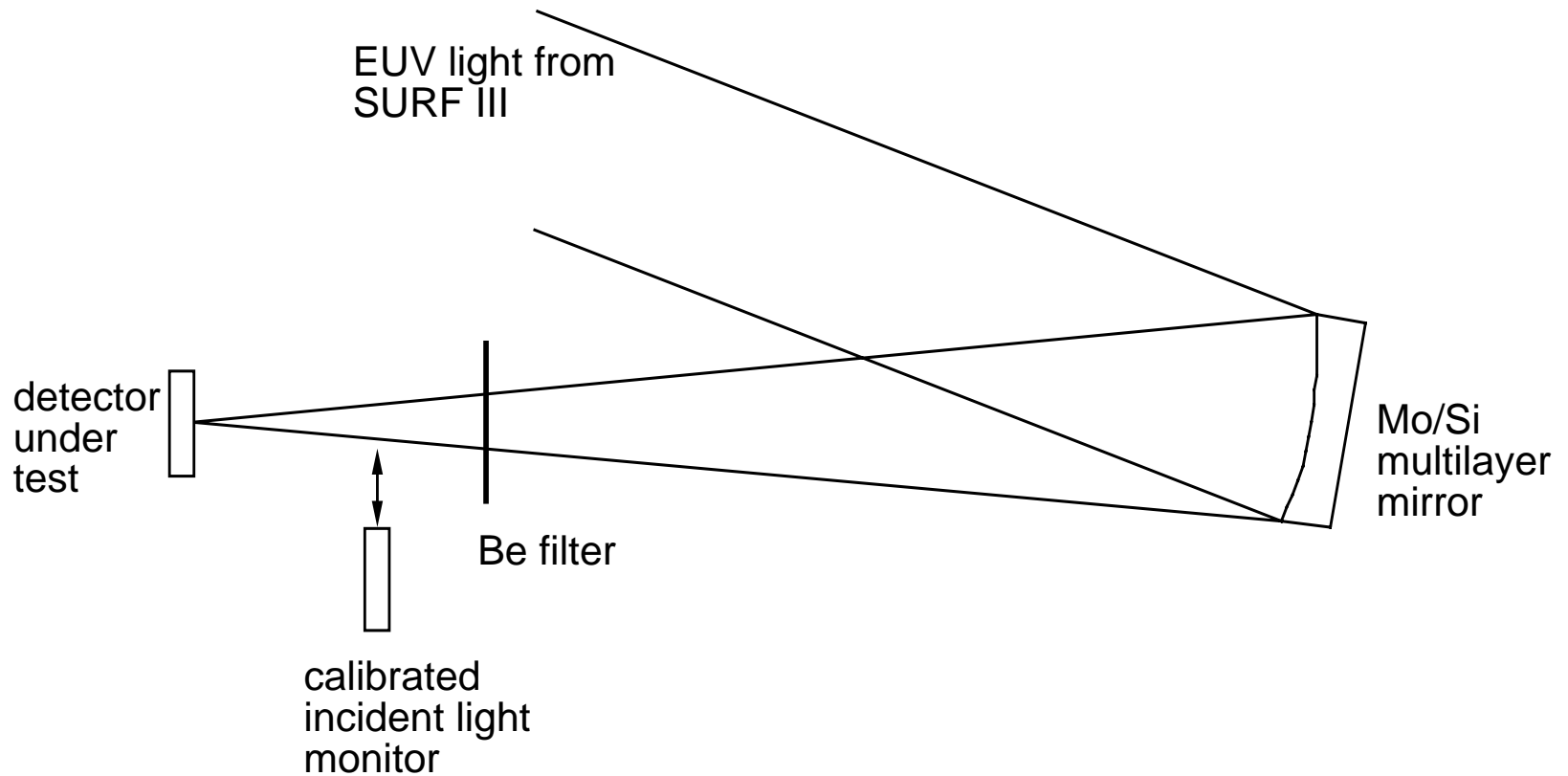
CW 532 nm measurements



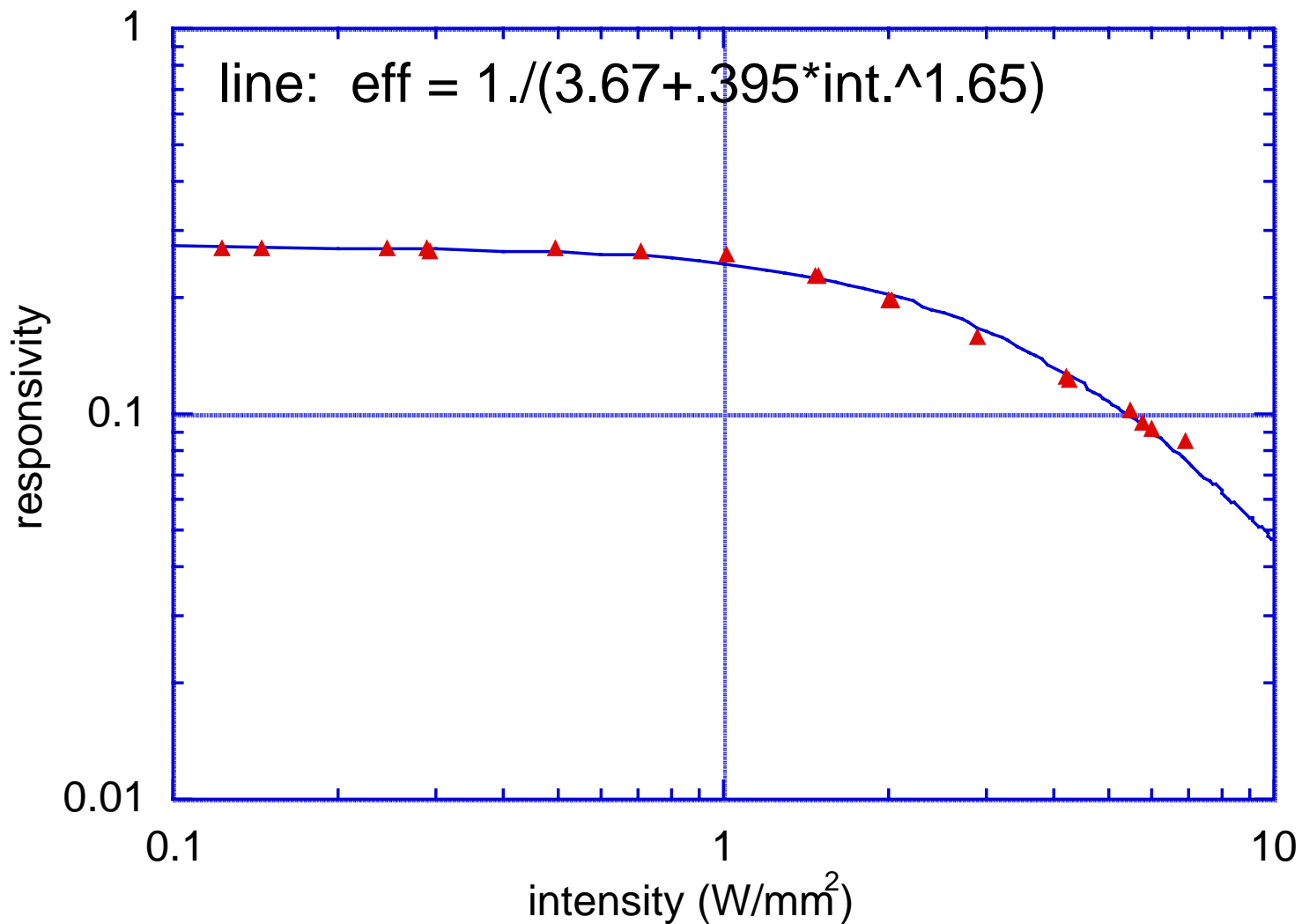
CW 532 nm results



CW EUV measurements



CW EUV results



CW work:

CW measurements were made on a different diode, which saturates at much lower intensities, because we did not have access to the extremely high intensities used in the pulsed 532 nm experiments.

The saturation data are qualitatively similar. The behavior at 532 nm CW can be described by the model developed for the pulsed work. The CW EUV, however, require an additional exponent in the denominator.

Future work:

- Carry out all three sets of measurements on identical diodes
- Calibrate diodes on a well-characterized laser-produced plasma source
- Further refine model to understand differences in 532 nm and EUV behavior