

## SPM Linearity

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### Introduction

At low optical signal levels the output of the SPM is proportional to the incident photon flux assuming that the optical signal is uniformly distributed across all microcells of the SPM. For continuous wave (cw) signals the incident photons produce an average photocurrent,  $I_p$ , that is proportional to the number of incident photons per second and is given by

$$I_p = N_{ph} \cdot PDE \cdot G \cdot q$$

where  $N_{ph}$  is the number of incident photons per second,  $PDE$  is the SPM photon detection efficiency,  $G$  is the gain of the SPM microcells and  $q$  is the electronic charge.

The SPM output is linear provided the rate at which the microcells detect photons is much less than the inverse of the microcell deadtime. The microcell deadtime is defined as the total time that the microcell is undergoing quenching and recovery. During the deadtime period an individual microcell cannot detect a photon incident upon it.

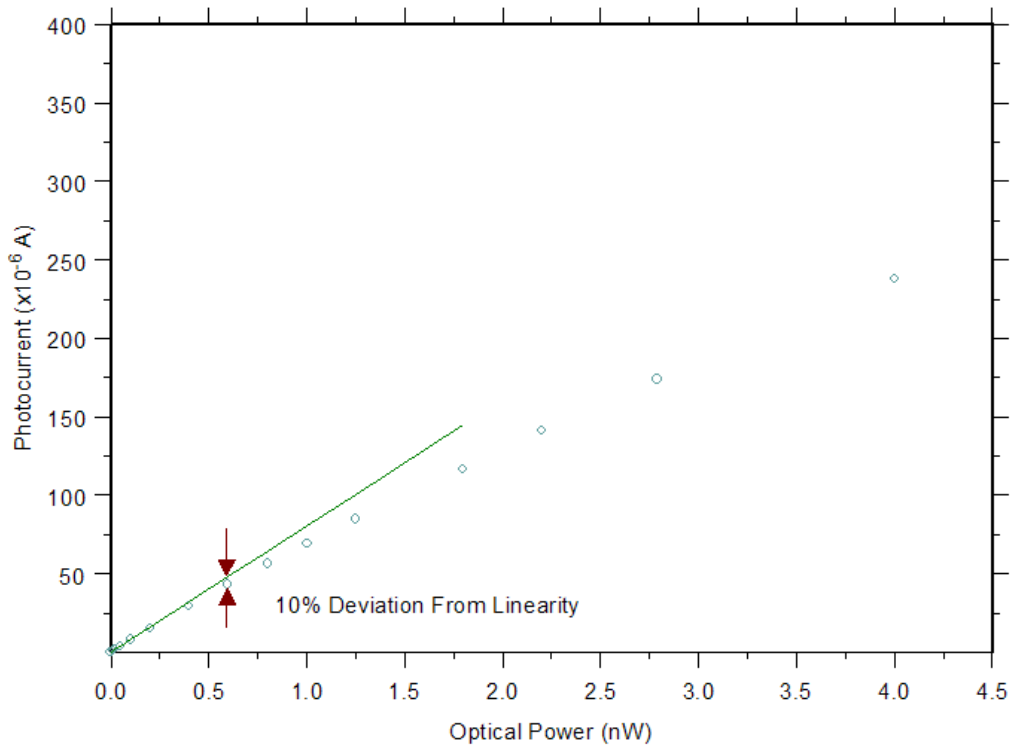
Above a certain signal level the SPM response becomes sub-linear. This is because the output pulse of a single microcell is independent of the number of incident photons that initiated the output pulse. As the number of incident photons per microcell per second increases, the probability that two or more photons initiate the output pulse increases. The SPM output begins to saturate when the number of detected photons begins to approach the number of microcells ( $M$ ),

$$N_{ph} \cdot PDE \rightarrow M$$

### Linearity – SPMMini1000X03A1

Figure 1 shows the SPM photocurrent as a function of optical power per mm<sup>2</sup> for a continuous wave signal at 520nm. The SPM is operated at –20°C and at a bias voltage of 29.5V or 2.5V above the breakdown voltage.

The point where the SPM response deviates by 10% from linearity is marked on the plot by arrows. For this measurement set-up the 10% deviation from linearity point occurs at an incident optical power of 0.6nW per SPM active area.



*Figure 1. SPMMini1000 photocurrent as a function of incident optical power per active area. At low optical power levels the photocurrent is proportional to the incident optical power. As the optical power increases the photocurrent begins to deviate from linearity. At  $0.6\text{nW}/\text{mm}^2$  the SPM photocurrent is 10% from the extrapolated linear line.*

### Linearity – SPM3000X03A1

Figure 2 shows the SPM3000 photocurrent as a function of optical power incident on the active area of the SPM3000 ( $2.85\text{mm}\times 2.85\text{mm}$ ) for a cw signal at 520nm. The point where the SPM response deviates by 10% from the extrapolated linear region is marked on the figure. In the case of this device the 10% deviation points occurs at  $0.55\text{nW}$  and is in reasonable agreement with the value obtained for the SPM1000.

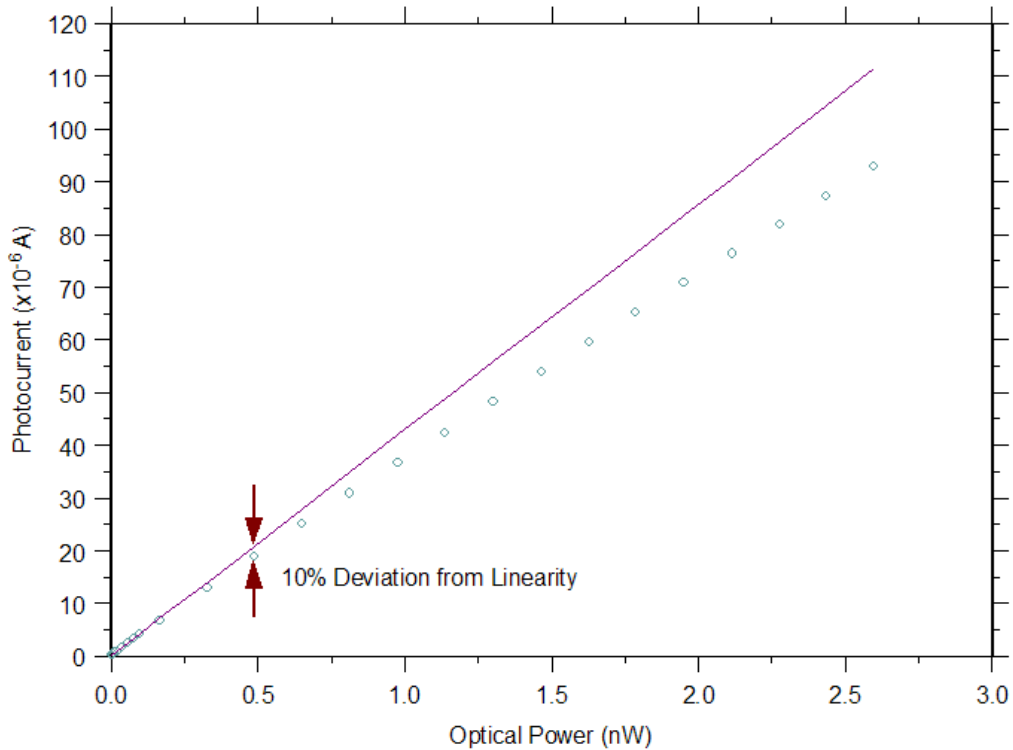


Figure 2. SPMMini3000 photocurrent as a function of incident optical power per active area. At low optical power levels the photocurrent is proportional to the incident optical power. As the optical power increases the photocurrent begins to deviate from linearity. At 0.55nW the SPM photocurrent is 10% from the extrapolated linear line.

## Summary

At low optical signal levels the SPM photocurrent is proportional to the incident optical power. As the optical power increases the SPM photocurrent begins to deviate from linearity due to the limited number of microcells. For a continuous wave signal of 520nm photons the 10% deviation from linearity point occurs at approximately 0.6nW and 0.55nW per SPM active area for the SPM1000 and SPM3000 respectively.