

Estimate of the surface dose and surface power density at BEAR

Sec.1 – Definition of quantities

Assume as indicated in Fig.1 the sample positioned at the point x along the beam propagation axis exposed to a beam of photons of energy $\hbar\omega$ impinging at time t onto a sample surface with a rate $N(\hbar\omega, t)$ ¹ and with a foot print $S(x)$.

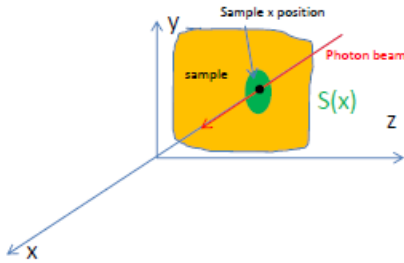


Fig.1 Frame of reference and definition of x_p , sample position along x axis, and beam foot print $S(x)$.

The impinging power $P(\hbar\omega, t)$ ² due to photon beam is

$$P(\hbar\omega, t) = N(\hbar\omega, t) \hbar\omega \quad [1]$$

the beam foot print onto sample surface is indicated as $S(x)$

The surface power density $F(\hbar\omega, t)$ ³ at time t is defined as the ratio of the

$$F(\hbar\omega, t) = P(\hbar\omega, t) / S(x) \quad [2]$$

while the surface dose $D(\hbar\omega, t, \Delta t)$ is defined as

$$D(\hbar\omega, t, \Delta t) = F(\hbar\omega) \Delta t \quad [3]$$

The photon beam intensity $N(\hbar\omega, t)$ is given in photon per s, the foot print $S(x)$ in cm^2 , the impinging power $P(\hbar\omega, t)$ in W, the surface power density in W/cm^2 and the surface dose density $D(\hbar\omega, t, \Delta t)$ in Joule/cm^2 .

The beam foot print is a function of x because of the horizontal and vertical divergence of the beam. Its minimum occurs at the focal point operatively defined as the position of the beam waist.

¹ $N(\hbar\omega, t)$ has dimensions of a frequency $[\text{T}^{-1}]$, the measure is given in invers of seconds (s^{-1}).

² $P(\hbar\omega, t)$ has the dimensions of power $[\text{ML}^2\text{T}^{-3}]$, the measure is given in Watt (W).

³ $F(\hbar\omega, t)$ has the dimensions of a surface power density $[\text{MLT}^{-3}]$, the measure is given in W/cm^2 .

Sec.2 – Experimental set up and procedure

The experimental and set up include

1. Setting of aperture (ψ_1 and ψ_2) of polarization selector
2. Setting of horizontal and vertical aperture of divergence selector
3. Higher orders suppression filter
4. Horizontal aperture of monochromator exit slit
5. Vertical aperture of monochromator exit slit
6. Selection of photon energy
7. Selection of the acquisition time of reading instrument (eg pico-ammeter or counter), default 1 s
8. Selection of the number N_{aq} of readings per point of acquisition variable (eg photon energy or kinetic energy)
9. Choice of experimental points pattern (y_M, z_M) of light spot position at sample surface
10. Choice of *in-focus* or *out-of-focus* sample position

follows with the relative numerical results at the time t of reference.

- **impinging power $P(\hbar\omega, t)$**

The number of impinging photon per s is obtained by a calibrated photodiode (IRD AXUV100) placed downstream the exposure point of samples and collecting the whole photon beam. From diode current through calibration curve the number of photons per s is obtained. Multiplication by photon energy gives power. The value $P(92, t) = 1.410^{-06}$ W was obtained.

- **beam foot print and beam waist**

the sample is positioned at focal point x (Fig.1). Beam foot print at this point is obtained by measuring the beam cross section at the focal point. To this end a metallic wire (Au) of $68 \mu m$ of diameter was positioned in the yz plane (Fig.1) in two different positions parallel to the y and z axis, respectively.

The wire was subsequently swept through the photon beam measuring simultaneously the emission current from wire. Beam y and z profiles of the kind reported in Fig.2 are obtained. Focus point x is obtained looking for the profiles with minimum FWHM.

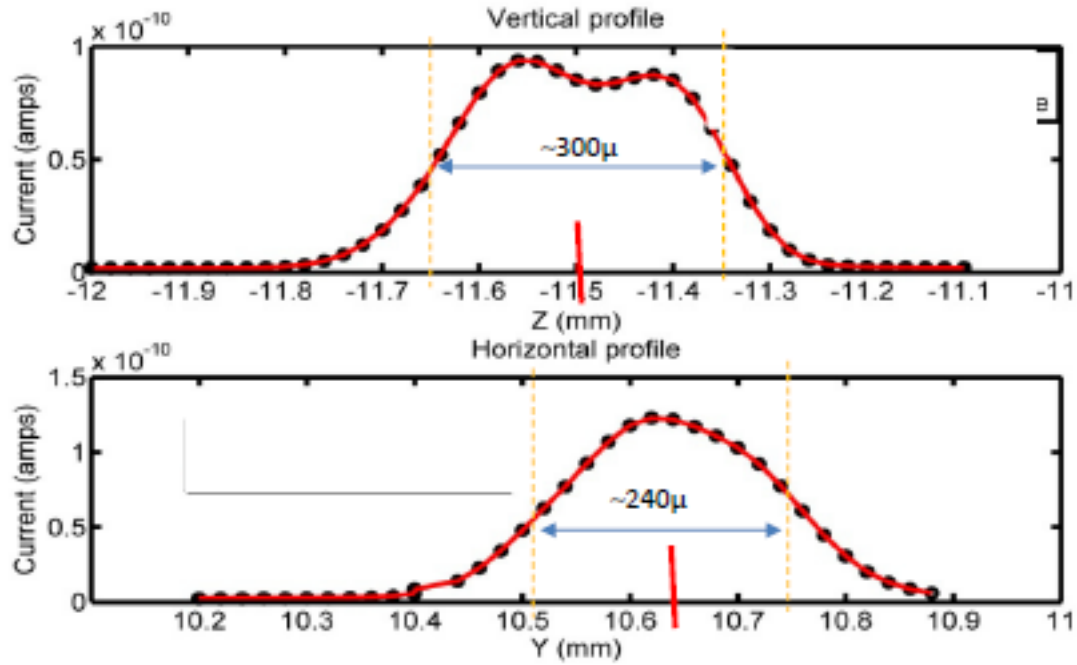


Fig. 1 - Beam profile in the vertical (upper) and horizontal (lower) directions at the focal point: full dots experimental points, Y and Z are the wire coordinate in the corresponding axes. Yellow dotted lines indicate inflection points of beam profile with relative distances in μm taken as the indicative horizontal X vertical dimension of beam cross section S. The estimated position of the centroid of the beam is indicated by the red bars on the y and z axis.

A analysis taking into account wire dimension and based on the deconvolution of the signal to extract beam profile was also attempted . The deconvoluted profiles are represented by the red curves of Fig.1.

According to these consideration for S the value $301 \times 224 \mu\text{m}^2 = 6.6 \cdot 10^{-4} \text{ cm}^2$ is assumed.

Inserting these values into eq.(2) for the surface power density at the instant of reference t one obtains

$$F(\hbar\omega, t) = 1.4 \cdot 10^{-6} / 6.6 \cdot 10^{-4} \text{ W/mm}^2 = 1.4 \cdot 10^{-6} / 6.6 \cdot 10^{-2} \text{ W/cm}^2 = 2.12 \text{ mW/cm}^2$$

Taking into account eq.[3] for the surface dose $D(\hbar\omega, t, \Delta t)$ for $\Delta t = 1 \text{ s}$ of exposure one obtains

$$D(\hbar\omega, t, \Delta t) = 2.12 \text{ mJ/cm}^2$$

This quantity depends linearly on Δt .

For light incidence different from zero (normal incidence) the foot print changes accordingly. With the sample at 45° , the power density must be divided by 1.42 due to the projection of the beam cross section onto the surface at this angle obtaining in present case the surface power density $\sim 1.5 \text{ mW/cm}^2$.

Impinging power depends on photon energy through the dependence of flux on energy. With photon energy also the distribution of power within the irradiated area changes though the overall irradiated area is not affected. This consideration allows to adapt this scheme to any photon energy.