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Quantitative Infrared Thermography on Carbon Stripper-Foils under Swift Heavy Ion Irradiation

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Abstract

Infrared thermography measurements of thin, semitransparent carbon foils under pulsed irradiation with 1.1 GeV uranium ions are presented. To convert the infrared signal into target temperature, the transmission and emissivity of carbon foils of various areal densities between 20 and 100 µg/cm2 were recorded. According to this calibration, a beam of $8x10^9$ U-ions/cm^2s leads to a temperature rise within a single ion pulse of 150 µs length of up to 350 C. This information is important for future simulations of beam induced damage processes occurring in high power targets.

1. Introduction

With increasing power of new accelerator facilities, new high performance materials and accelerator components are needed in order to withstand enhanced degradation by radiation damage, thermal effects, and stress waves. Solid foil strippers have been used for many years in ion accelerator technology for efficient electron stripping of ion beams. New challenges evolve with high beam intensities and a pulsed beam structure as foreseen at the planned Facility for Antiproton and Ion Research (FAIR) at GSI Helmholtzzentrum für Schwerionenforschung. A reliable working carbon stripper foil as well as the prediction and increase of its lifetime are of great interest regarding the exposure to extreme beam conditions. In order to understand the failure mechanism of the foils, the knowledge of foil temperature during irradiation is crucial. This work presents a first approach of measuring the temperature in the beam spot of a thin semitransparent carbon foil during irradiation by infrared thermography. Due to semitransparency of the stripper foils, a method for measuring the transmittance, emissivity and taking into account the background influence on the infrared signal had to be developed.

2. Experimental

Amorphous carbon stripper foils of different thicknesses (20, 30, 50, 97 µg/cm²) were installed in front of a box heating the foil and acting as a black body (Fig. 1, right). By using a copper sheet of known emissivity placed between the foil and the heat box, the background and finally the transmittance of the carbon foils could be calculated by the ratio: $\tau_{obj} = R_{env}/R_{obj}$. Emissivity values for foils of different thicknesses were calculated by applying: $\varepsilon_{obj} = 1 - \rho_{obj} - \tau_{obj}$, where ε is the emissivity, ρ the reflectance and τ the transmittance of the foil. The reflectance was assumed to be 4%. Resulting emissivity and transmittance values for different stripper foils are presented in Fig 1 (left). The emissivity increases exponentially with the thickness of the amorphous carbon foils. The calculated values were used as input parameters for the measurement of the temperature evolution during beam exposure of the foils (Fig. 2). The transmittance of a CaF_2 window similar to that of the infrared viewport of the irradiation chamber was measured. The resulting value of 87.2% was also used in the calculations.

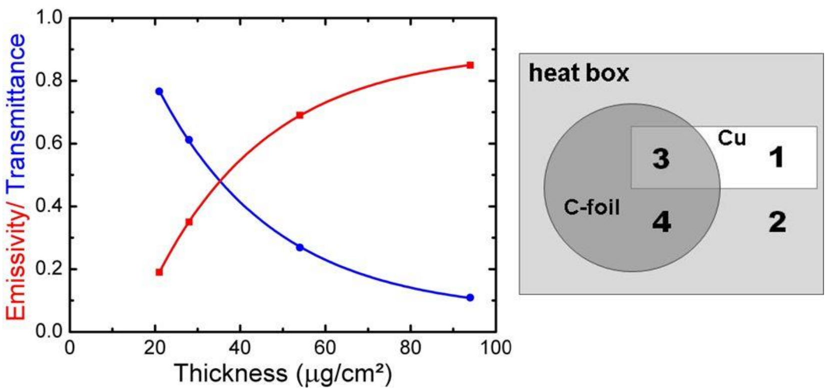

Fig. 1. *Measured emissivity and transmittance (left) values for foils of different thicknesses and radiance measurement setup (right).*

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3. Preliminary Results

Figure 2 shows the temperature evolution in the beam spot of a semitransparent 30 µg/cm² carbon foil under irradiation of 1.1 GeV U ions of 150 µs pulse length. The rise of the temperature within each beam pulse is clearly observable in the timing graph (Fig. 2 (left)). Table 1 shows flux, energy density, and observed temperatures. The peak temperature increases significantly for thicker foils, reaching a maximum temperature of 353°C in the 97 µg/cm² foil.

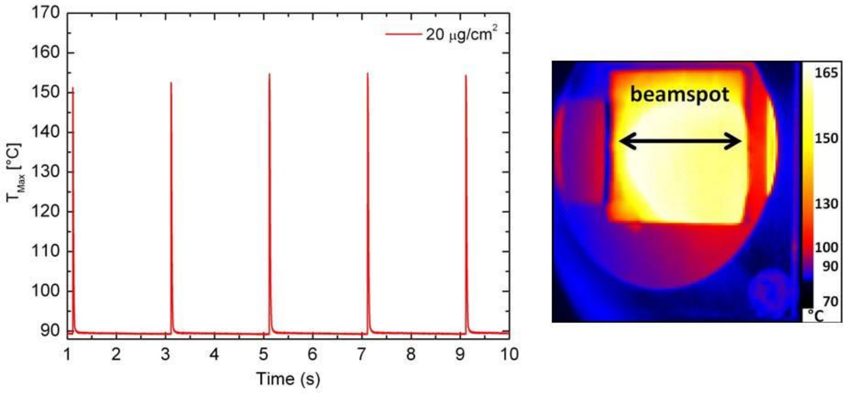

Fig. 2. *Time evolution (left) and spatial gradient (right) of temperature in the beam spot during irradiation of a 30 µg/cm² carbon foil with a 1.1 GeV U ions.*

Table 1. *Parameters of irradiation with 1.1 GeV U ions and measured maximum beam-induced temperature for amorphous carbon foils of different thickness.*

Thickness [µg/cm²]	Flux [ions/pulse cm²]	Power Density [kW/g pulse]	T(max) [°C]
20	7.30E+09	388.8	155
30	7.50E+09	399.4	163
50	7.00E+09	372.8	205
97	7.70E+09	410.1	353

A new setup is currently under development for reducing the influence of the beam-induced heating in chamber elements behind the semitransparent foil. Additionally, a concept considering these effects is developed for the calculation of more accurate temperatures.