Infrared Imaging Video Bolometer with a Double Layer Absorbing Foil

16th International Toki Conference

Advanced Diagnostics for Burning Plasmas

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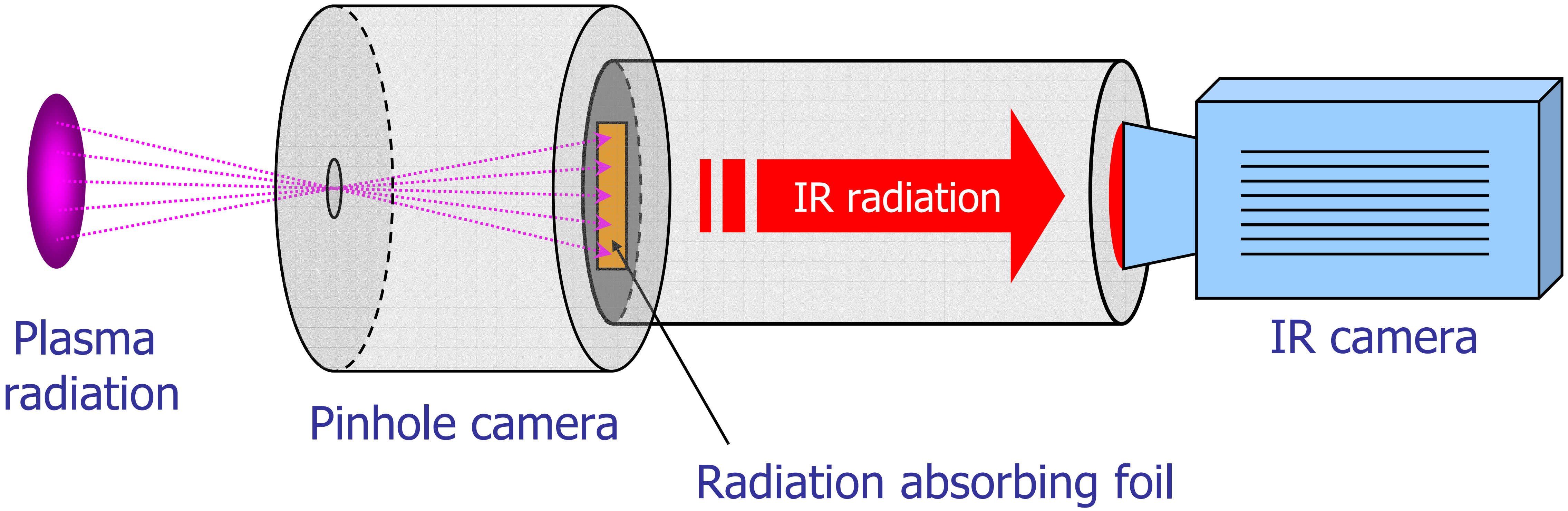
Motivations and goal

- Large size, 1 or 2.5 microns thick golden foil used as an IRVB absorber is very fragile.
- Gold has a very high heat conductance (λ = 315 W/m×k) which makes the incident radiation energy flux flow widely distributed across the IRVB foil (crosstalk effect). Therefore a special numerical procedure is needed to reconstruct the incident radiation image, which decreases the sensitivity of the bolometer.

- The **goal** of the work is to develop an IRVB foil which is mechanically strong, absorbs incident radiation effectively and has minimal (ideally zero) heat conductance to minimize the crosstalk effect.

IR video bolometer operation principle



Double layer foil structure

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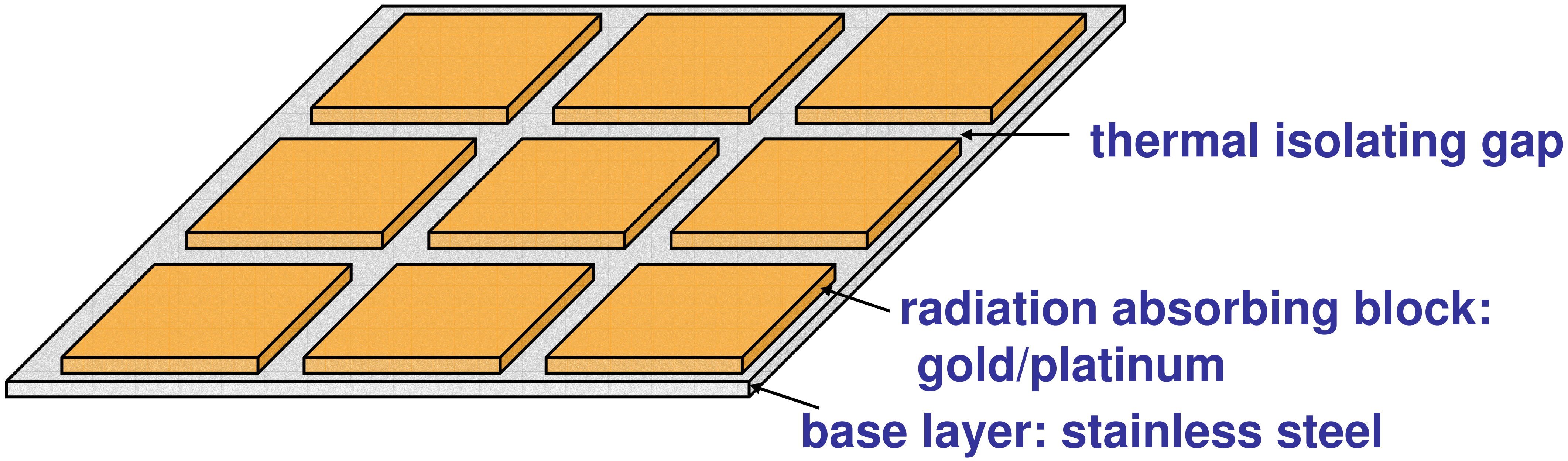

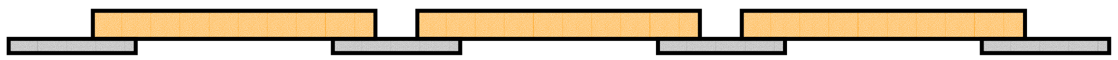

cross section of a double layer foil with perforated base

Base perforation reduces the foil mass and accelerates the thermal response

Double layer foil prototype

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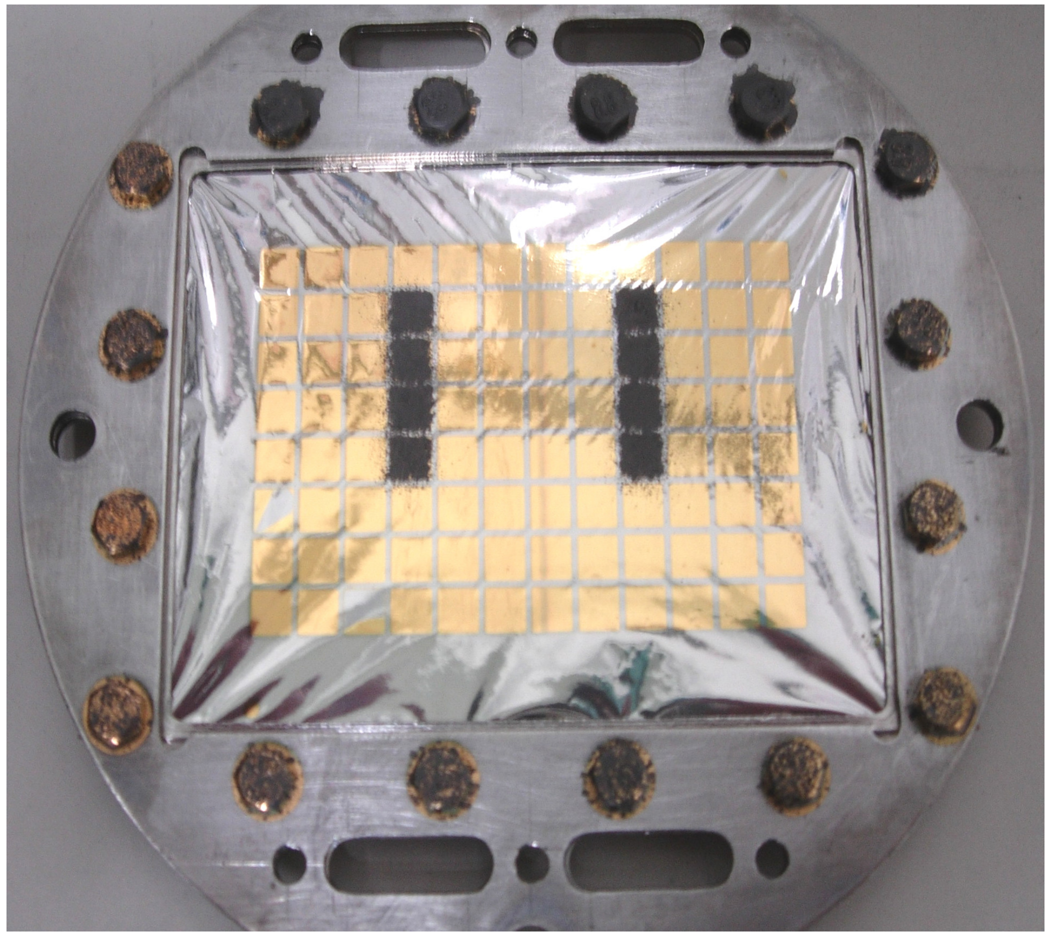
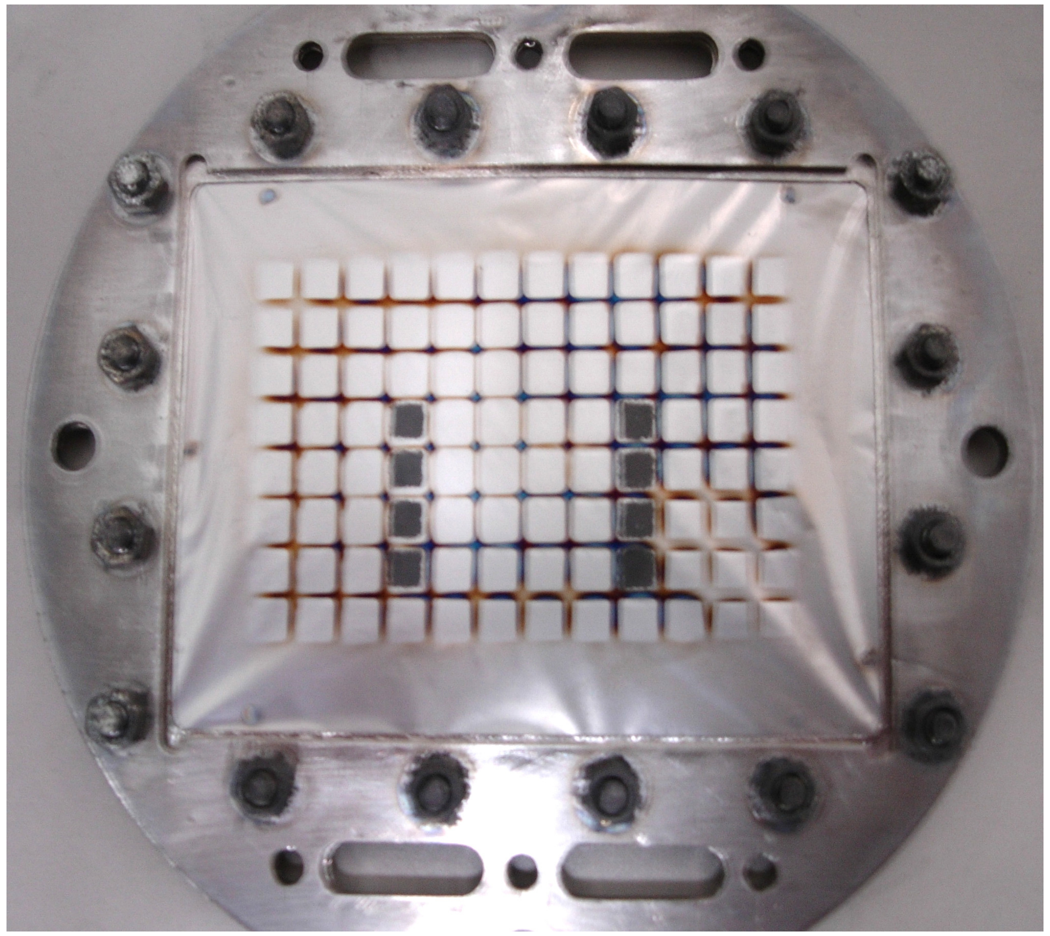


Front (radiation absorbing) side
Gold: 2.1 ± 0.1 / 0.85 ± 0.1 micron
Manufacturing process:
vacuum vapor deposition



Back (IR camera viewed) side
Stainless steel: 2.5 ± 0.1 micron
Manufacturing processes:
electrochemical etching,
ion beam etching

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Finite element method simulation of the foil thermal evolution

Incident radiation

IR radiation $\sigma T^4 \sim 4\sigma T_r^3(T-T_r)$

Heat transfer to 4 neighbor elements

$$\frac{T_{t+1,x,y}-T_{t,x,y}}{\Delta t}=\frac{F_{x,y}+R\left(T_{t,x,y}-T_r\right)+\frac{2\lambda_{x,y}\lambda_{x\pm1,y}}{\lambda_{x,y}+\lambda_{x\pm1,y}}\left(T_{t,x\pm1,y}-T_{t,x,y}\right)+\frac{2\lambda_{x,y}\lambda_{x,y\pm1}}{\lambda_{x,y}+\lambda_{x,y\pm1}}\left(T_{t,x,y\pm1}-T_{t,x,y\pm1}\right)}{C_{x,y}}$$

Temperature increment

Heat capacitance

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Simulation - experiment comparison DLF, golden foil

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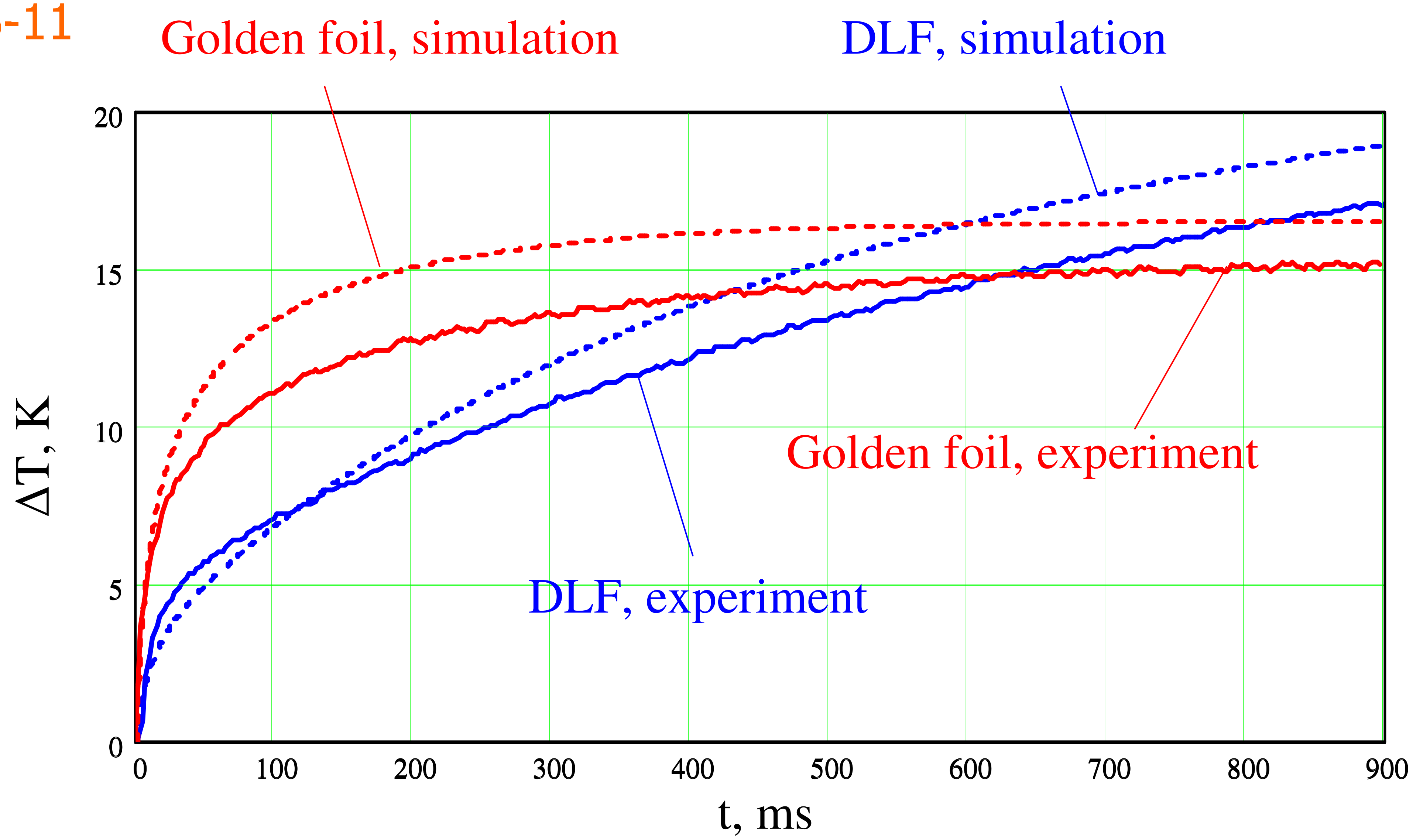
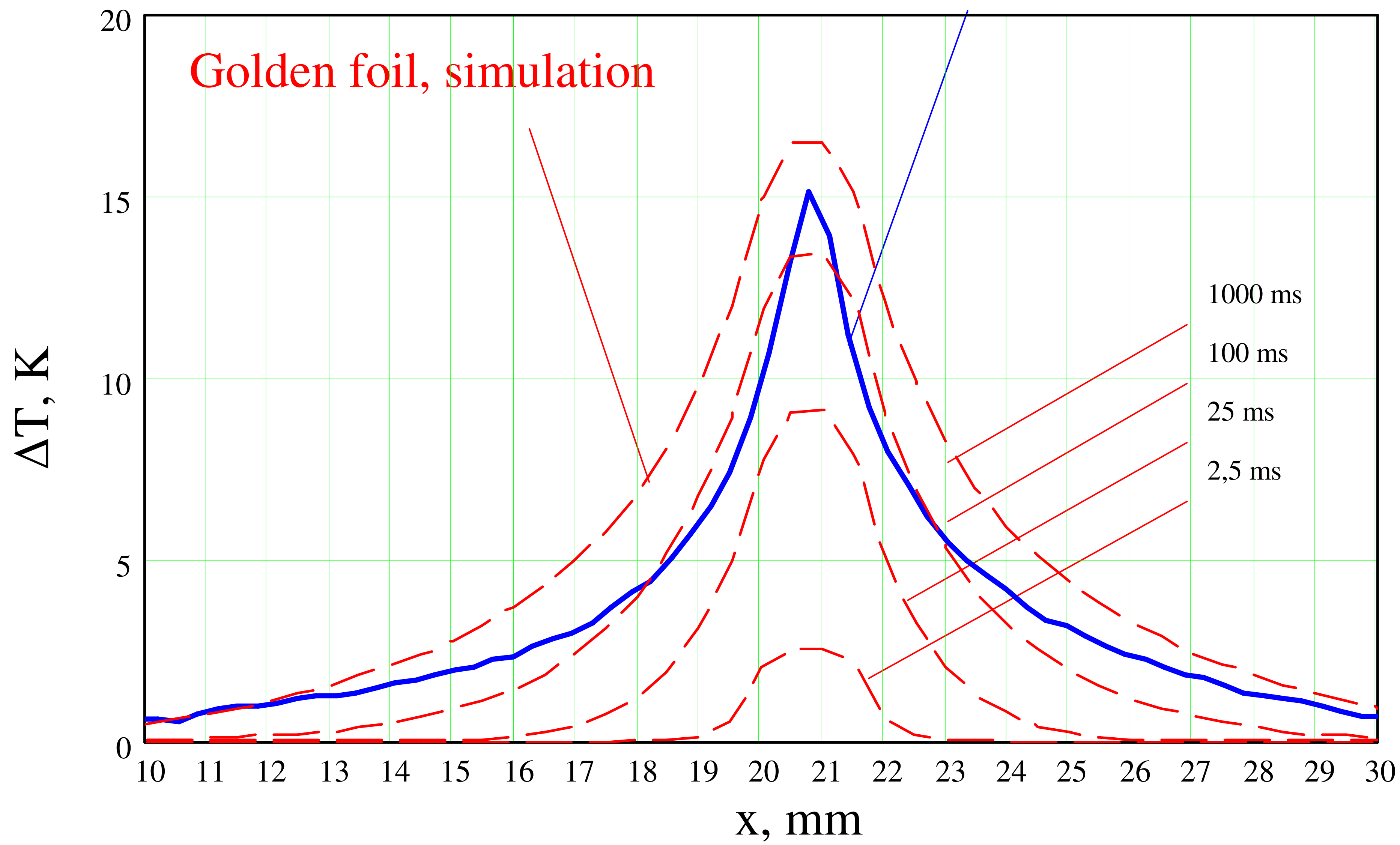


Thermal response of the DLF and 2.5 microns golden foil to the 18 mW laser beam shutter opening. FEM simulation and experimental data

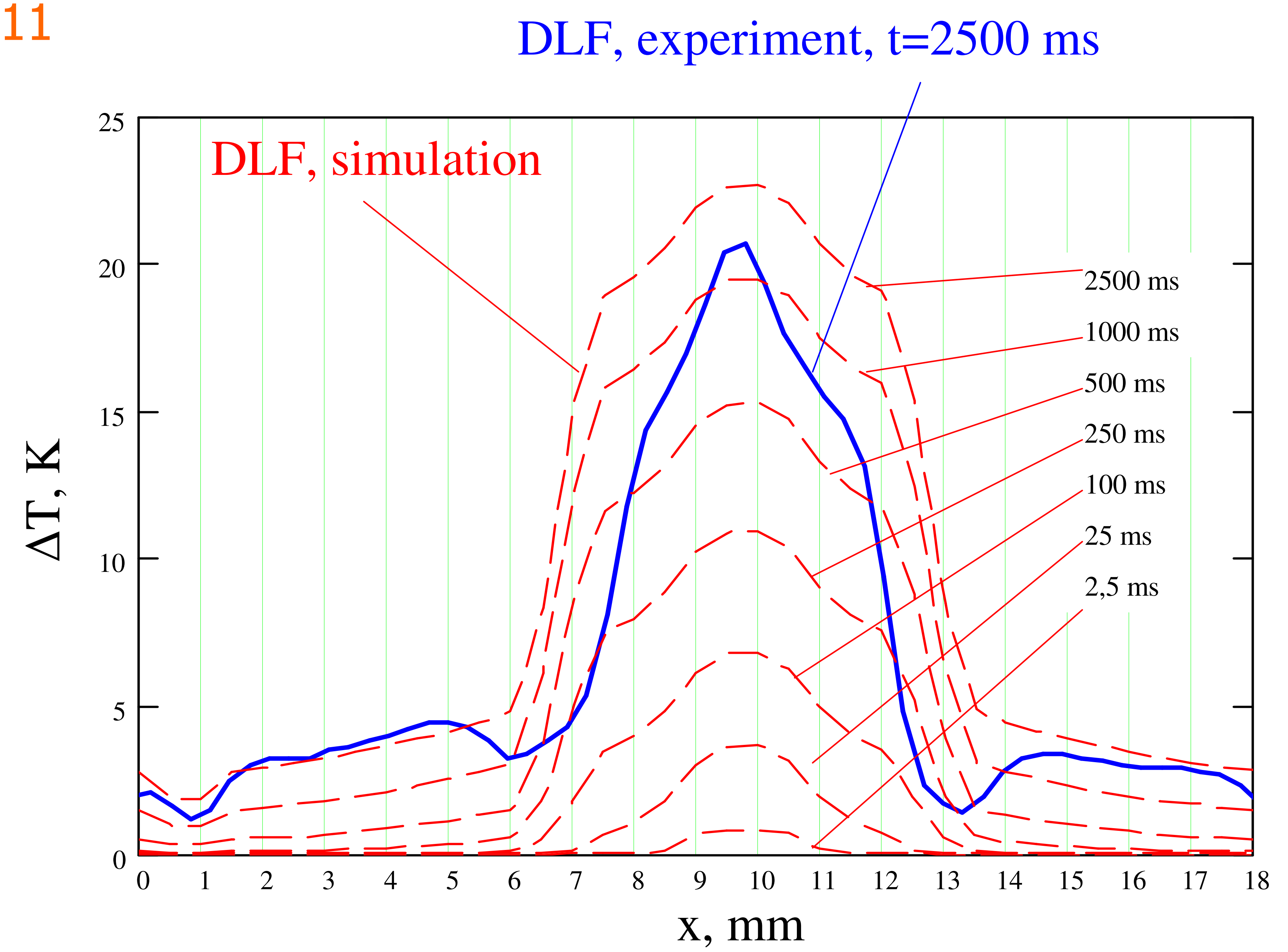
Temperature profiles evolution, golden foil

Golden foil, experiment, t=1000 ms



2.5 microns golden foil, simulation – experiment comparison

Temperature profiles evolution, DLF prototype



DLF, simulation – experiment comparison

Thermal response

DLF prototype / golden foil

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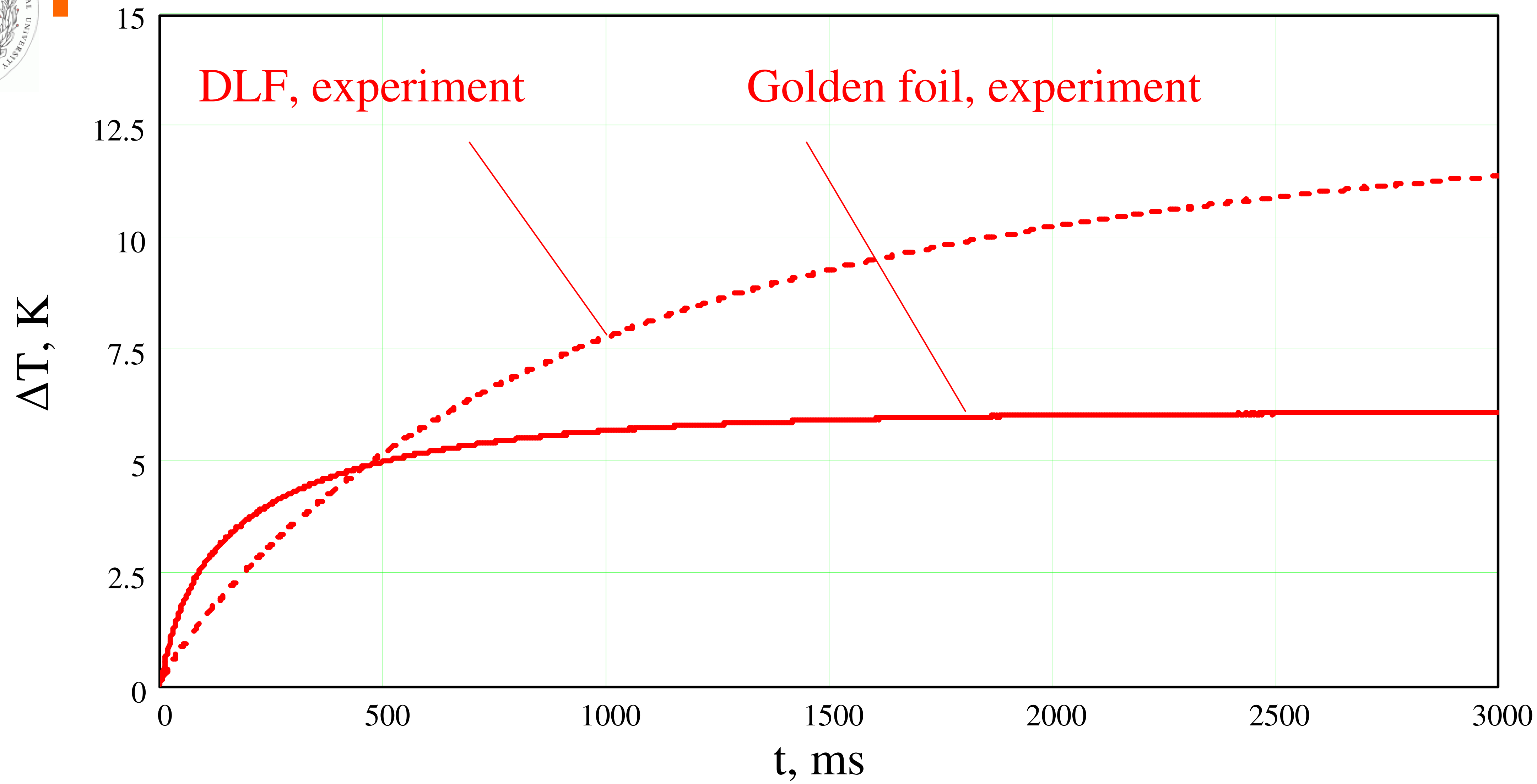

Thermal response of the DLF and 2.5 microns golden foil to the 15 mW laser beam shutter opening. Experimental data.

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Thermal response

DLF / golden foil (ITER applicable foils)

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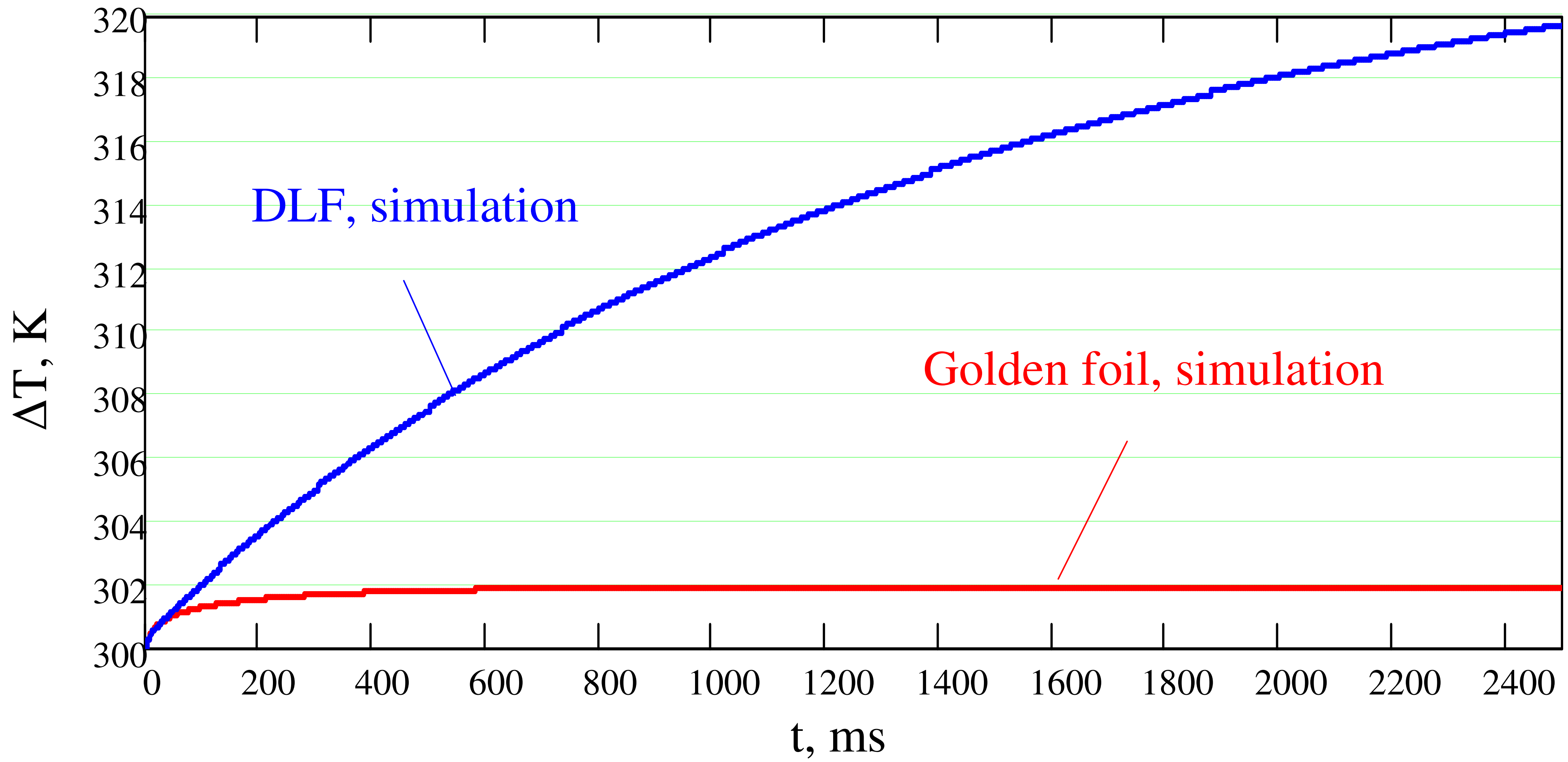

Thermal response of the 10 microns gold / 2 microns stainless steel DLF and 10 microns golden foil to the 14.7 mW / Ø 5 mm laser beam shutter opening. FEM simulation

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Conclusions

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- The double layer foil for an infrared video bolometer is a simply produced material which allows us to improve the IRVB sensitivity. A first prototype of the DLF has shown thermal response equal to that of similar golden foil at 500 ms signal rise time. The DLF sensitivity at 0 Hz is twice better than golden foil sensitivity. Further improvement should be achieved by use of a thinner (1 micron) base foil.
- A simple rectangular grid finite element method simulation of the foil response was shown to be an adequate instrument to predict foil thermal properties.
- For ITER applications where the thickness of the absorbers should be increased to at least 10 microns the slow thermal response of the DLF is 10 times higher than that of the golden foil.
- DLF in its present embodiment does not allow a change of the size of the bolometer pixel (part of the foil considered as one bolometer "channel"). The problem can be solved by miniaturizing the DLF pattern.