# Estimation of Tungsten melt-zone size occurred during transient heat loads using COMSOL Multiphysics


**Presented by**

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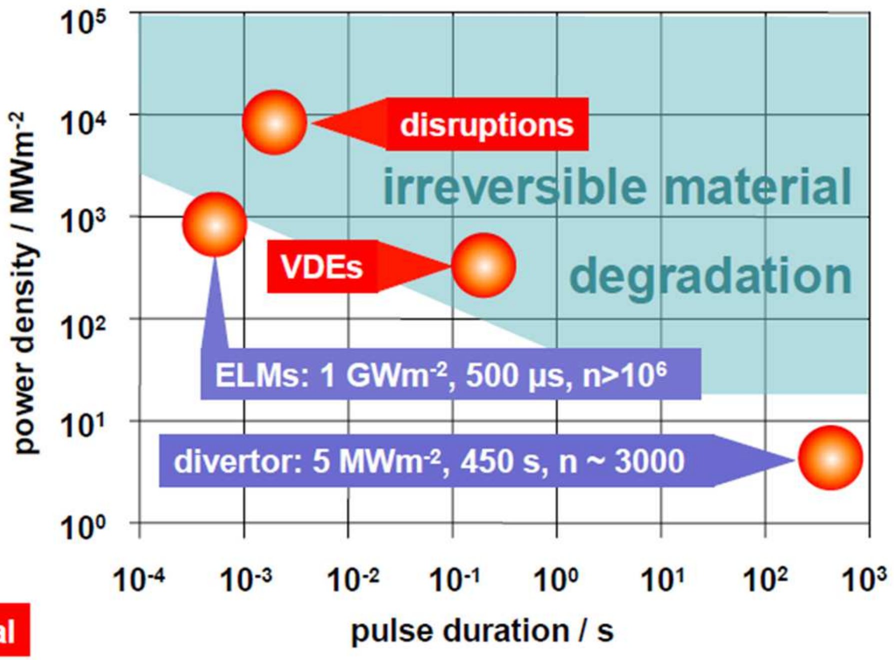
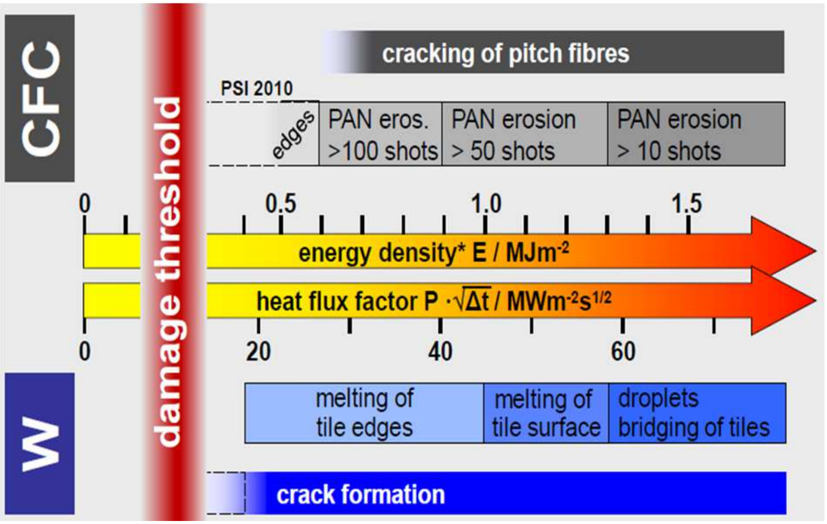
# Outline

- ❖ **Introduction and Objective**
- ❖ **Tungsten melt-zone size calculation using COMSOL Multiphysics simulation**
- ❖ **Tungsten melt-zone size calculation by analytical equations**
- ❖ **Tungsten melt-zone size measurement by MATLAB image processing**
- ❖ **Conclusion**

# Introduction and Objective




Transient heat load events are spontaneously occurred in the fusion reactor.

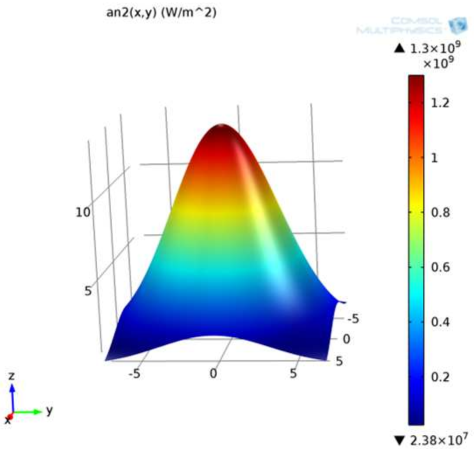
Tungsten is a prime plasma facing material in present as well as future fusion reactors. Melting threshold of the pure tungsten is ~ $20MW/m^2t^{0.5}$

❖ The Objectives of this work is to estimate the size of tungsten melt-zone formed during the transient heat load event simulated using the high power electron beam system.


*R. A. Pitts et al., Phys. Scr. T138 (2009) 014001*

*J. Linke et al, Nucl. Fusion 51 (2011) 073017*

# Tungsten melt-zone size calculation by COMSOL simulation



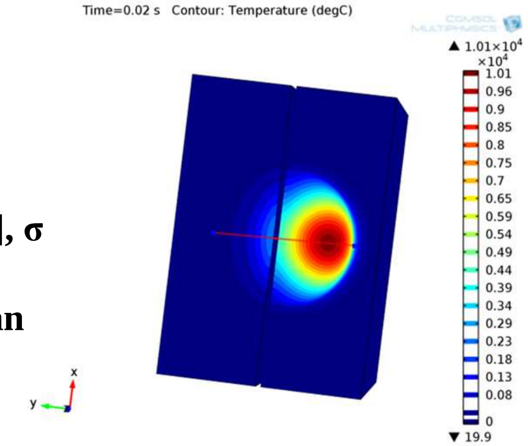

3D plot of Gaussian heat flux used for simulation

**Gaussian function**

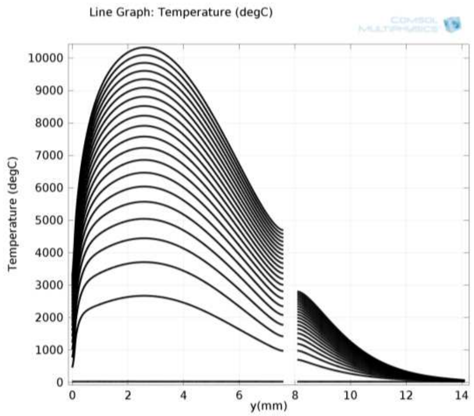
$$I(x,y) = \frac{P}{2\pi\sigma^2} e^{\frac{-(x^2+y^2)}{2\sigma^2}}$$

**Where, P Total beam power [kW], σ standard deviation[mm], q heat flux [W/m2], FWHM of Gaussian =2σ**

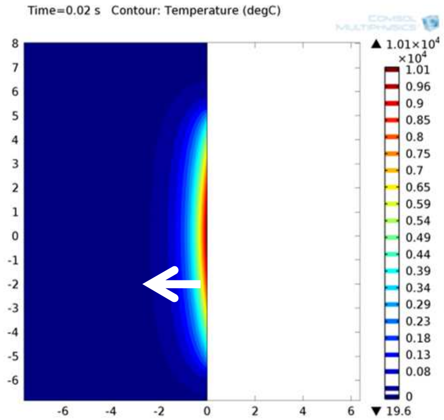
## 3D –Temperature contour plot



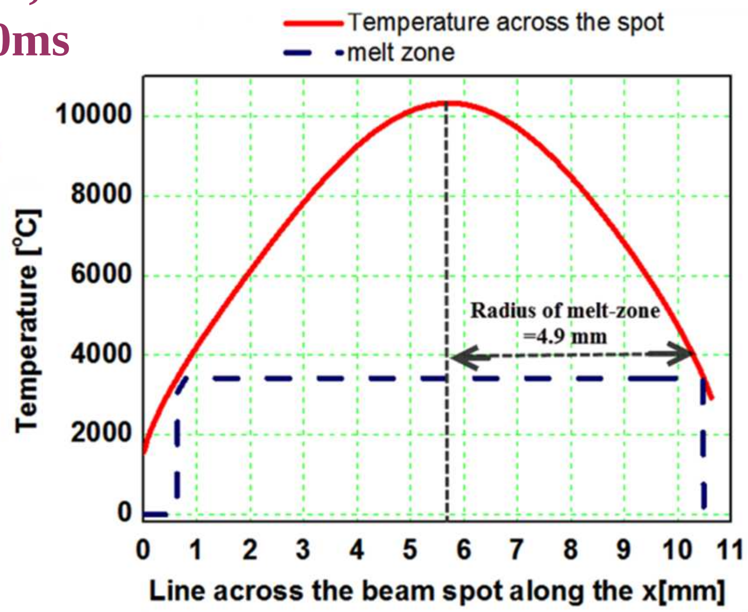

**Present case σ = 3.5, P= 100kW, time= 20ms**




**Temperature across the beam spot along the y direction for all time steps**

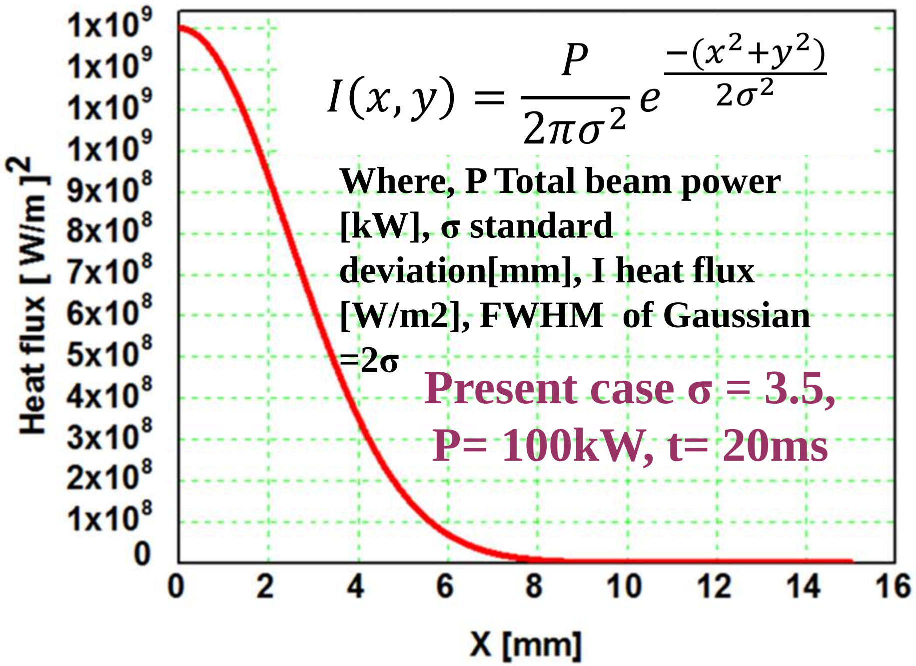



**Penetration depth inside tile = 1.8mm**

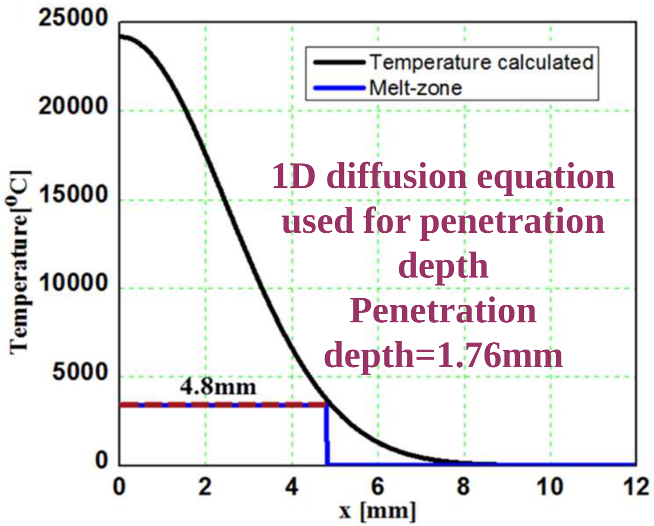



**Radius of a Tungsten melt-zone by COMSOL simulation study is equal to 4.9mm**

# Tungsten melt-zone size calculation by analytical equations




Gaussian heat flux profile used for analytical calculation



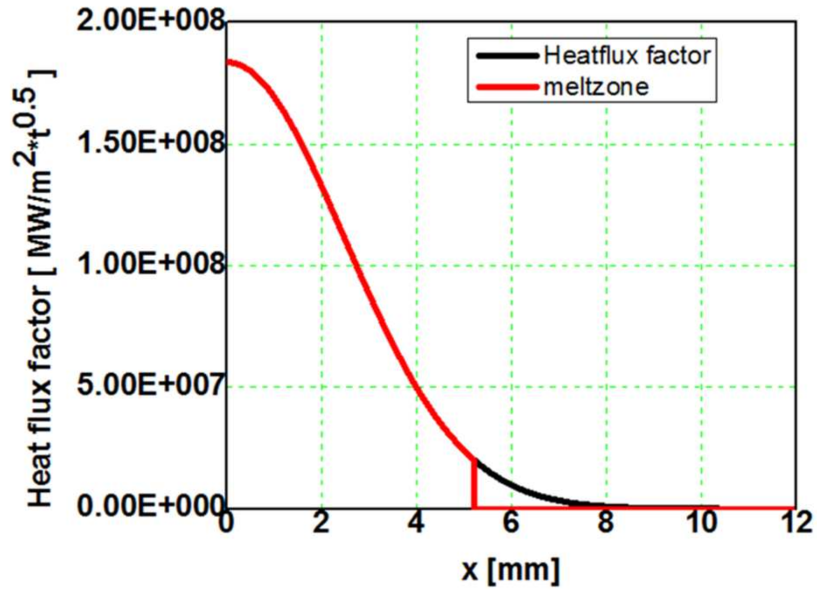

**Surface temperature calculation by Semi-infinite surface area without cooling.**

$$\Delta T = 2P\left(\frac{t}{\pi k\rho c}\right)^{1/2} \text{-------(1)}$$

**Where, P absorbed heat flux W/m2, K Thermal conductivity [W/m k], p Density c specific heat capacity [J/K. Kg]**

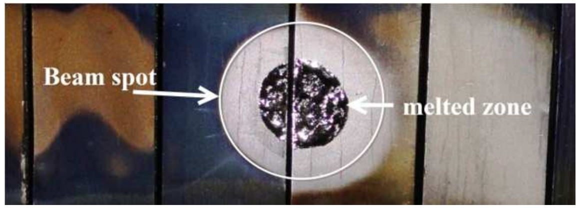
**Penetration depth is :**

$$D = \left(\frac{2tk}{\rho c}\right)^{1/2} \text{--------(2)}$$

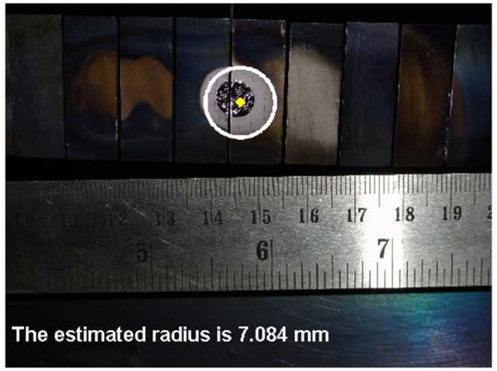



*T. Hirai, G. Pintsuk, Fusion Engineering and Design 82 (2007) 389–393*

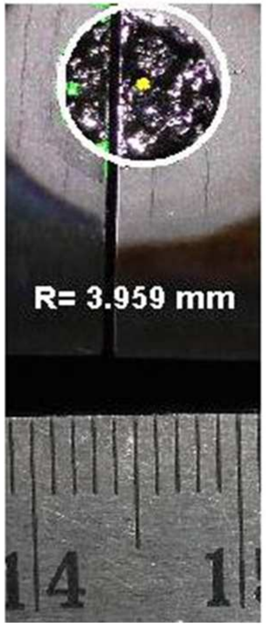
# Tungsten melt-zone size measurement by MATLAB image processing




Radius of melt zone by MATLAB program




Radius of beam spot by MATLAB program




| Experimentally measured Radius of Tungsten melt-zone | Tungsten melt-zone radius calculated by Analytical solution & Heat flux factor | Tungsten melt-zone radius calculated by Comsol Multiphysics |
|---|---|---|
| 4 mm | 4.8mm | 4.9mm |

## MATLAB Script for estimation of beam spot size and melt zone

```
I=imread('C:\Users\Yashashri\Desktop\4.jpg');
imshow(I);
I2=rgb2gray(I);
T=graythresh(I);
BW=im2bw(I2,T);

dim=size(BW);
r=dim(2);
col=round(dim(2)/2)-59;
row=find(BW(:,col),1);

connectivity = 8;
num_points   = 850;
contour = bwtraceboundary(BW, [row, col], 'N', connectivity, num_points);
imshow(I);
hold on;
plot(contour(:,2),contour(:,1),'g','LineWidth',1);
x = contour(:,2);
y = contour(:,1);

% solve for parameters a, b, and c in the least-squares sense by
% using the backslash operator
abc = [x y ones(length(x),1)] \ -(x.^2+y.^2);
a = abc(1); b = abc(2); c = abc(3);

% calculate the location of the center and the radius
xc = -a/2;
yc = -b/2;
radius  =  sqrt((xc^2+yc^2)-c);
```

## Conclusion

**Effective area of the Gaussian heat pulse where the heat flux factor greater than equal to the tungsten melting threshold factor ~ $20 MW/m^2 t^{0.5}$ is responsible for melting of the tungsten surface.**

# THANK YOU