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Ignition of Aluminum Particles

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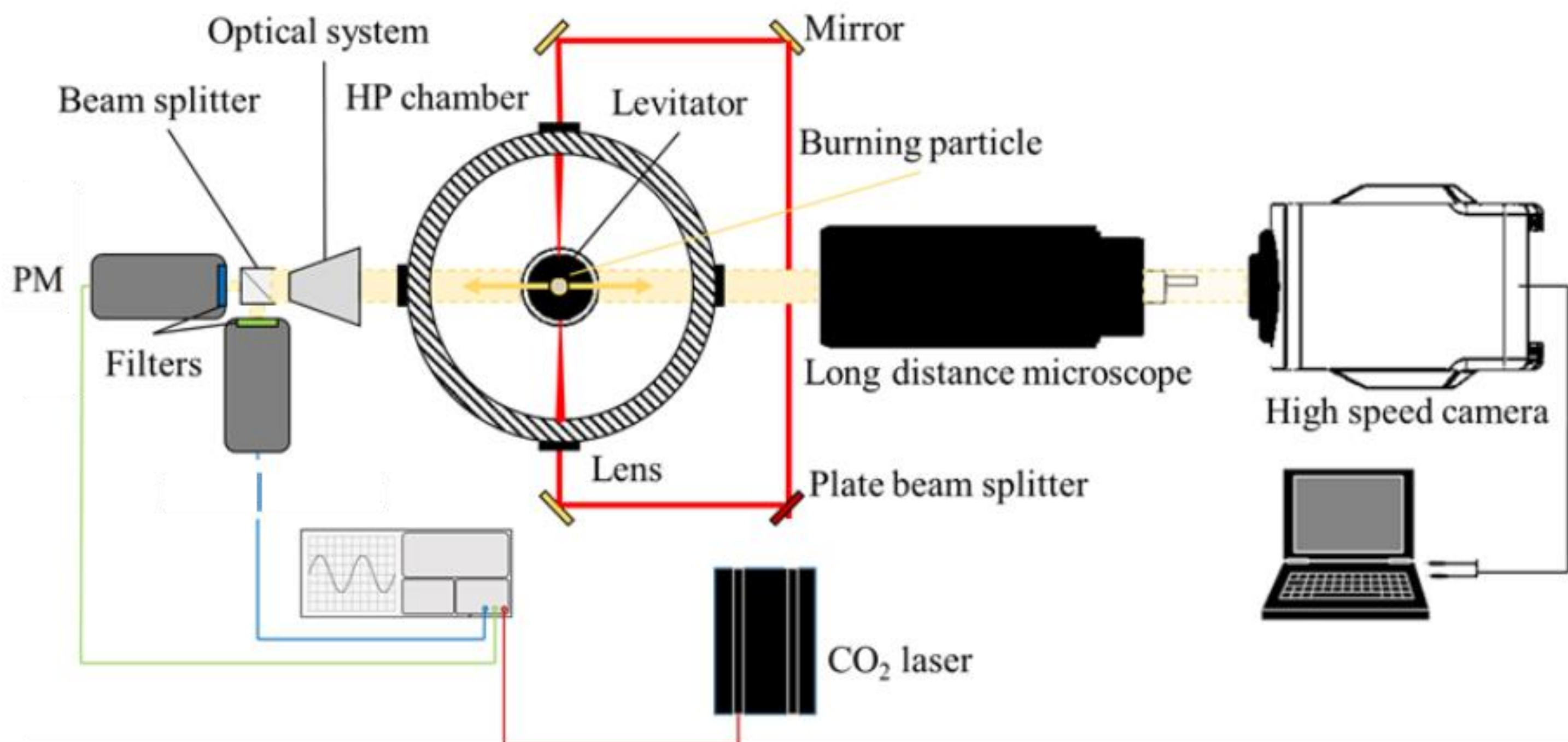
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Objective:

Characterization of the ignition process of an isolated aluminum particle through visual information and temperature measurement. Results are compared to a simple model.

Experimental Setup, The Electrodynamic Levitator



- Levitating **charged particle** in a controlled atmosphere
- **Symmetrically heated** by a splitted CO2 laser beam ($\lambda = 10.6\text{nm}$)
- **High speed PHANTOM camera** combined with long distance microscope QUESTAR QM100 allowing a **1.92 $\mu\text{m}/\text{px}$** magnification
- 39000 fps and 768x768 px resolution

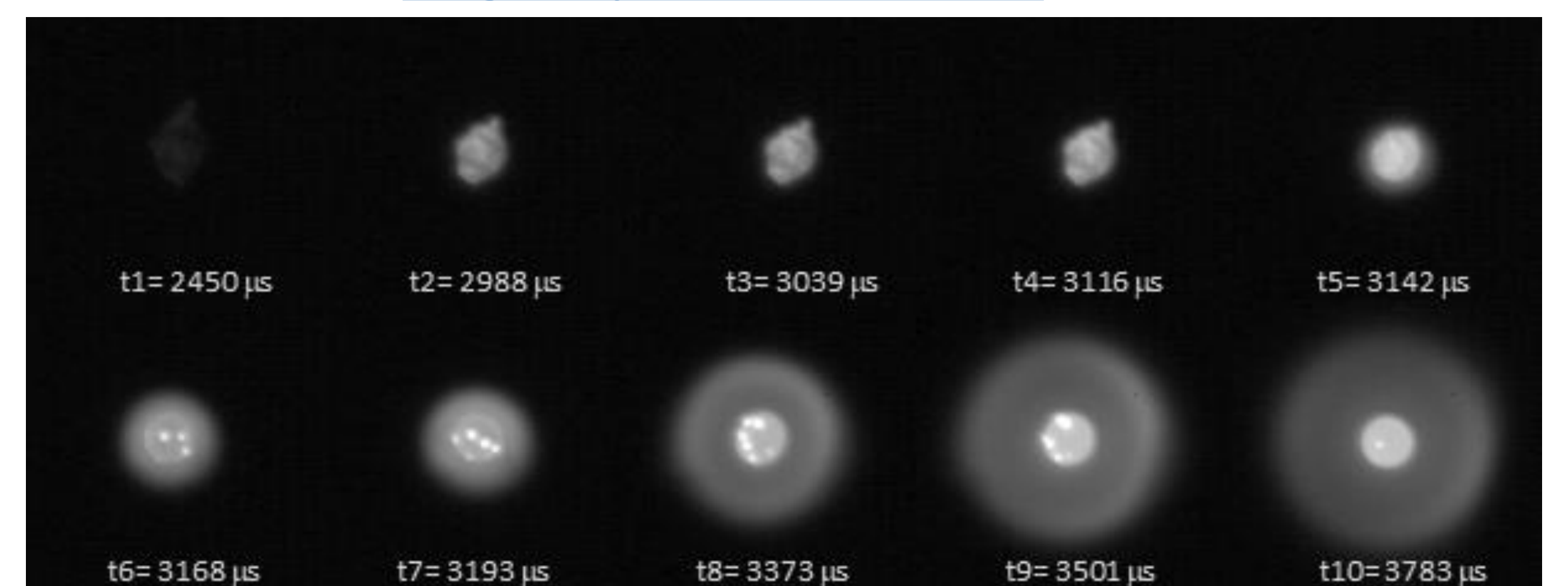
Two-color ratio pyrometry:

- Photomultipliers equipped with interference filters
- $\lambda_1 = 720\text{ nm}$; $\lambda_2 = 830\text{ nm}$ to avoid emission lines of main gaseous species
- Ratio of radiative intensities at different wavelengths: $\Gamma = \frac{L_{\lambda_1}}{L_{\lambda_2}}$
- Absorption along the line of sight is neglected
- Grey body assumption and Planck's law: $T = f(\Gamma, \lambda_1, \lambda_2)$
- Calibration made with a Quartz Tungsten halogen lamp



Temporally resolved, integrated temperature of the condensed phase

High Speed Camera:

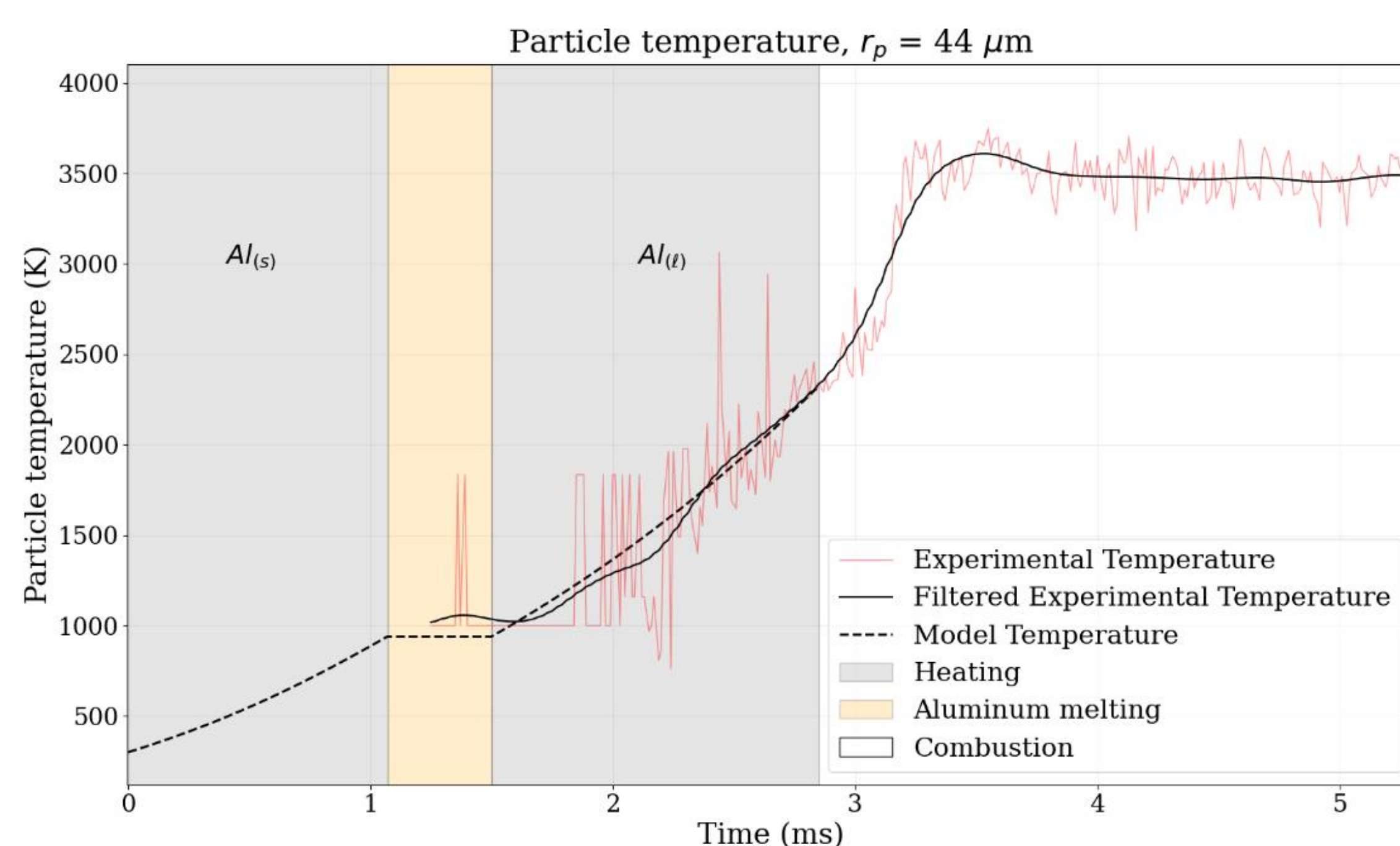
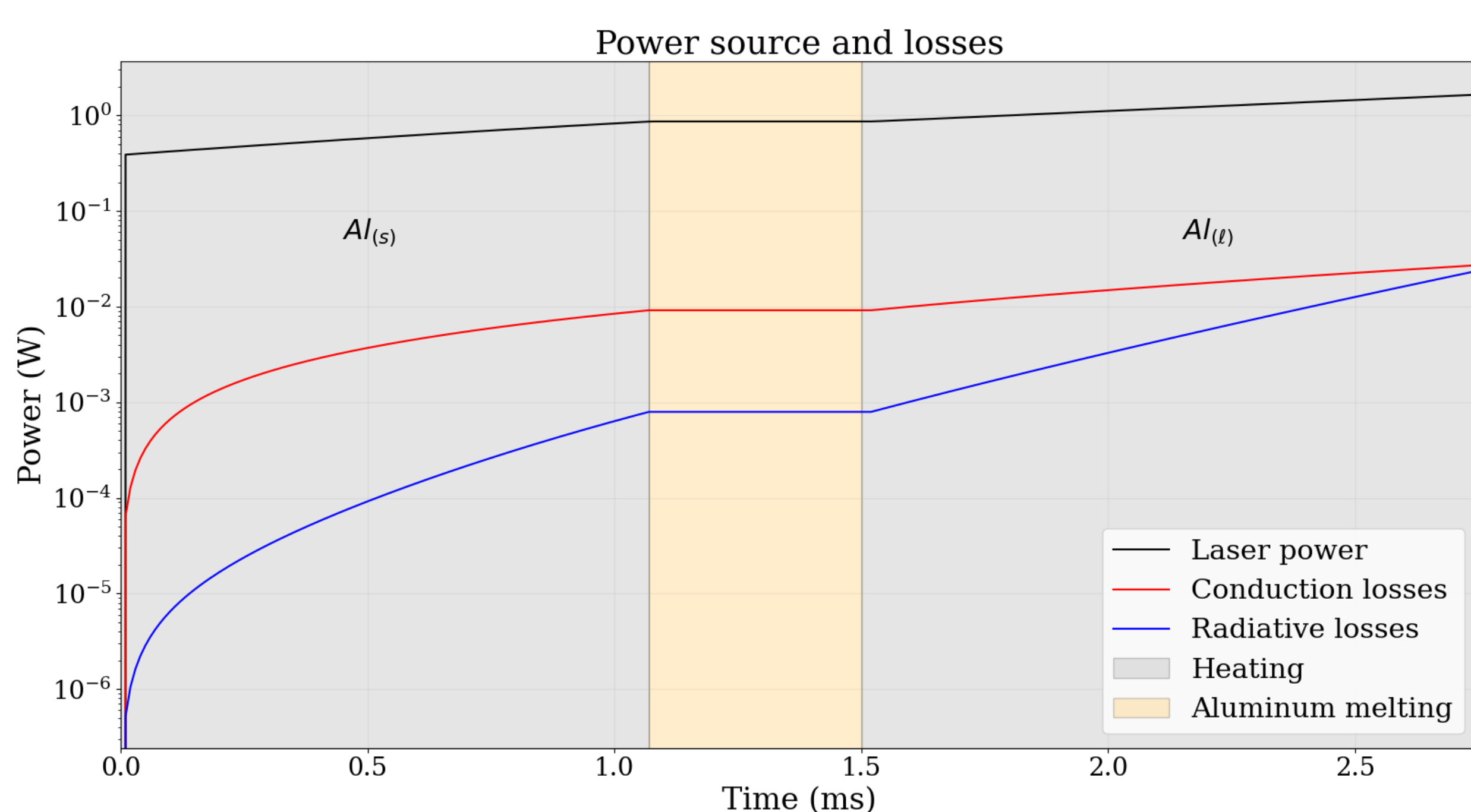


Model Description:

- **Power source:** single Gaussian laser beam integrated on the projected surface of the particle. Absorption efficiency accounts for the amount of laser energy given to the particle. The remaining energy is scattered.
- **Power losses:** conduction, radiation
- **Convection is neglected** due to the staticity of the particle and the absence of induced flow
- Power used to **heat and melt** the particle
- Biot number $Bi \ll 1$: Temperature gradients inside the particle are neglected
- η_{abs} linearly varying between 0.018 to 0.08

$$\underbrace{\eta_{abs} \int_{z_p-r_p}^{z_p+r_p} \int_{-(r_p^2-(z-z_p)^2)^{0.5}}^{(r_p^2-(z-z_p)^2)^{0.5}} \frac{W}{2\pi\sigma^2} e^{-\frac{y^2}{2\sigma^2}} e^{-\frac{z^2}{2\sigma^2}} dy dz}_{Q_{laser}} = \underbrace{m_p c_p \frac{dT}{dt}}_{Q_{heat}} + \underbrace{L_{Al} \frac{dm_{Al}^{liq}}{dt}}_{Q_{melt}} + \underbrace{\lambda_{env} 4\pi r_p (T_p - T_0)}_{Q_{cond}} + \underbrace{\sigma_{SB} \epsilon_{Al_2O_3} (T^4 - T_0^4)}_{Q_{rad}}$$

Results:



- 3 phases: heating, melting and heating
- Power from the laser is two order of magnitudes higher than thermal losses: **adiabatic process**
- No experimental data below 1200K due to required exposition time
- Combustion temperature around 3500K
- Good prediction: Almost zero exothermic surface reaction

