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Ignition of Aluminum Particles

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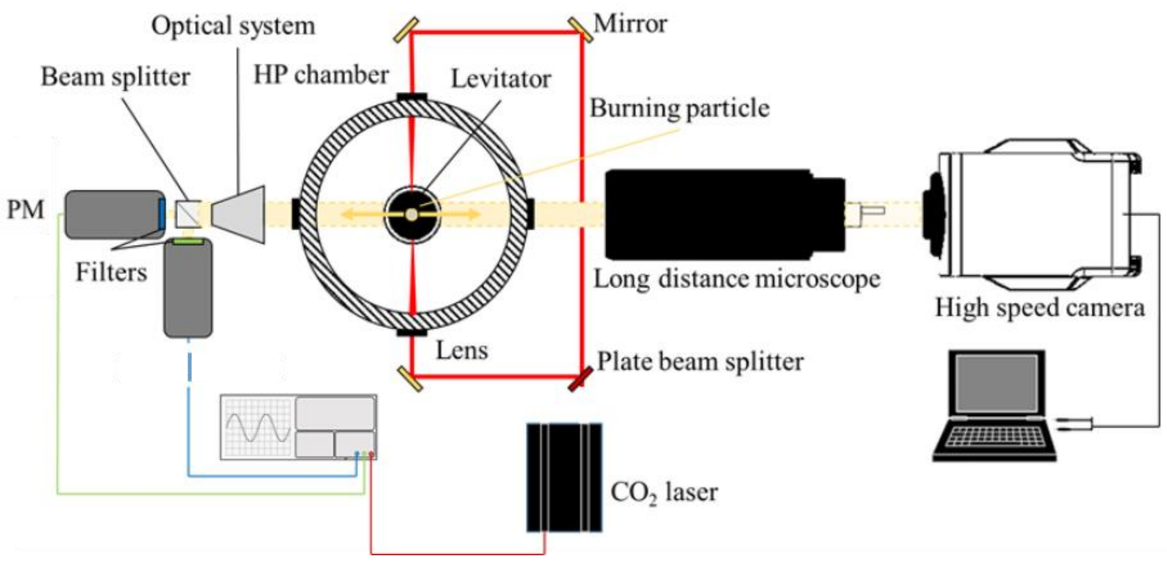
Objective:

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



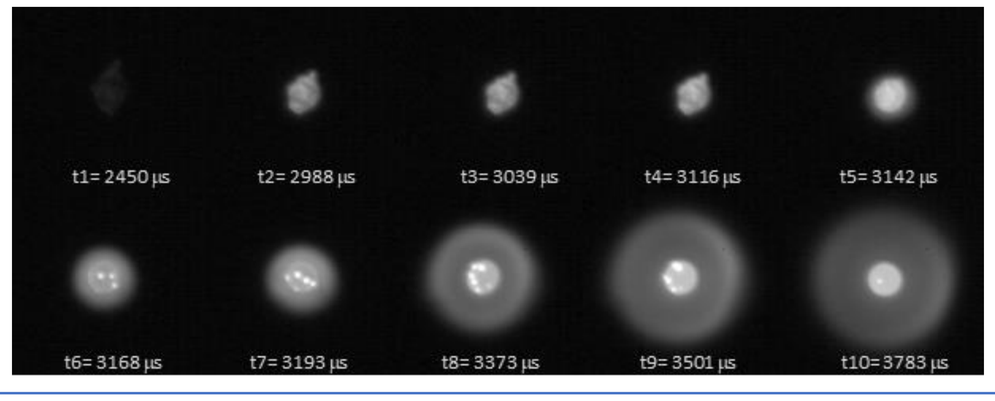
- Levitating **charged particle** in a controlled atmosphere
- **Symmetrically heated** by a splitted CO2 laser beam ($\lambda = 10.6$nm)
- **High speed** PHANTOM **camera** combined with long distance microscope QUESTAR QM100 allowing a **1.92 µm/px** magnification
- 39000 fps and 768x768 px resolution

Two-color ratio pyrometry:

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

Temporally resolved, integrated temperature of the condensed phase

High Speed Camera:

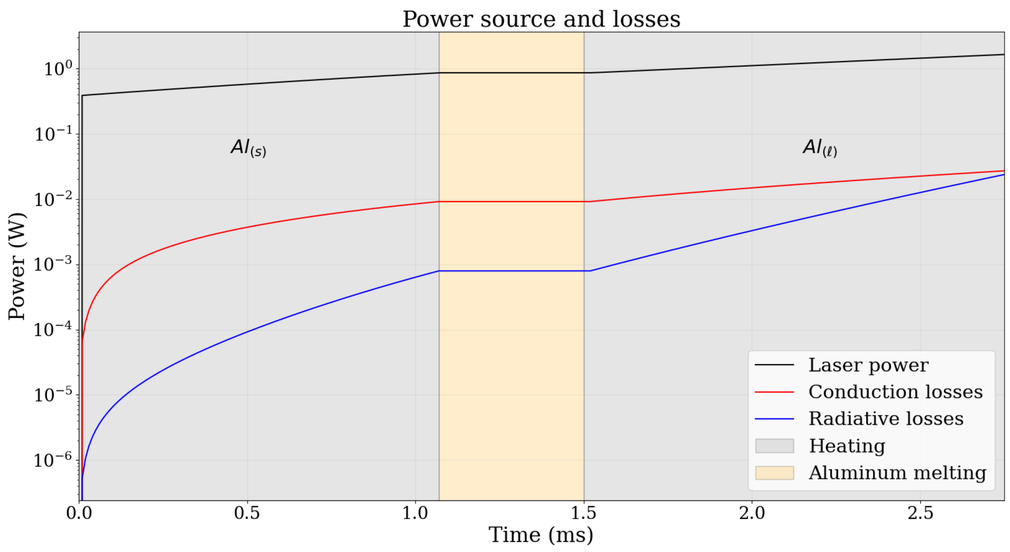


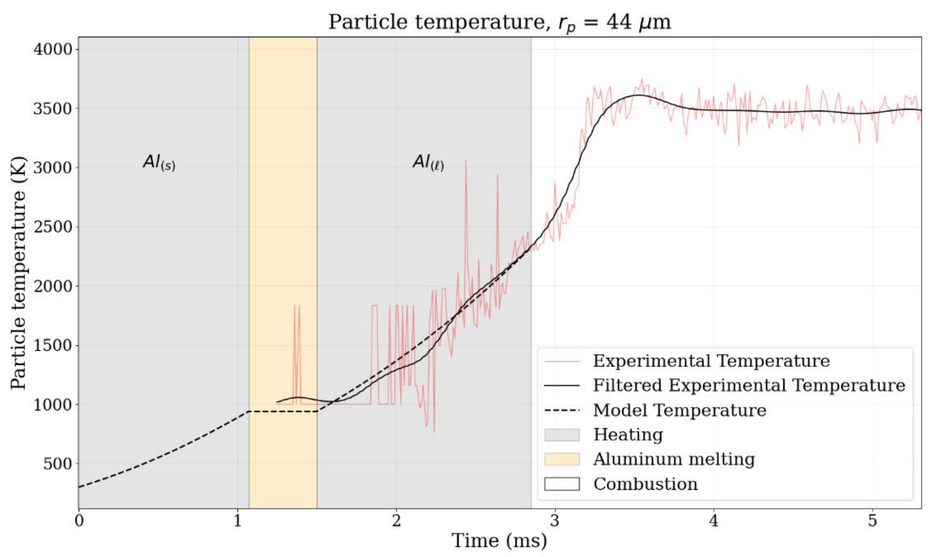
Model Description:

- **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 $\boldsymbol{Bi \ll 1}$: Temperature gradients inside the particle are neglected
- η_{abs} linearly varying between 0.018 to 0.08

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

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