Geo-Energy

- Subsurface CO_2 storage
- Geothermal energy
- Induced seismicity
- Subsurface activities

Center for Isotope Research

- Greenhouse gases
- Aerosols
- Stable isotope applications
- Radiocarbon analysis & dating

Science & Society Group

- Embedment of technology & innovation
- Sustainable energy & local conditions
- Biobased society & biotechnology in Africa

energy ESRIG sustainability

Combustion Technology

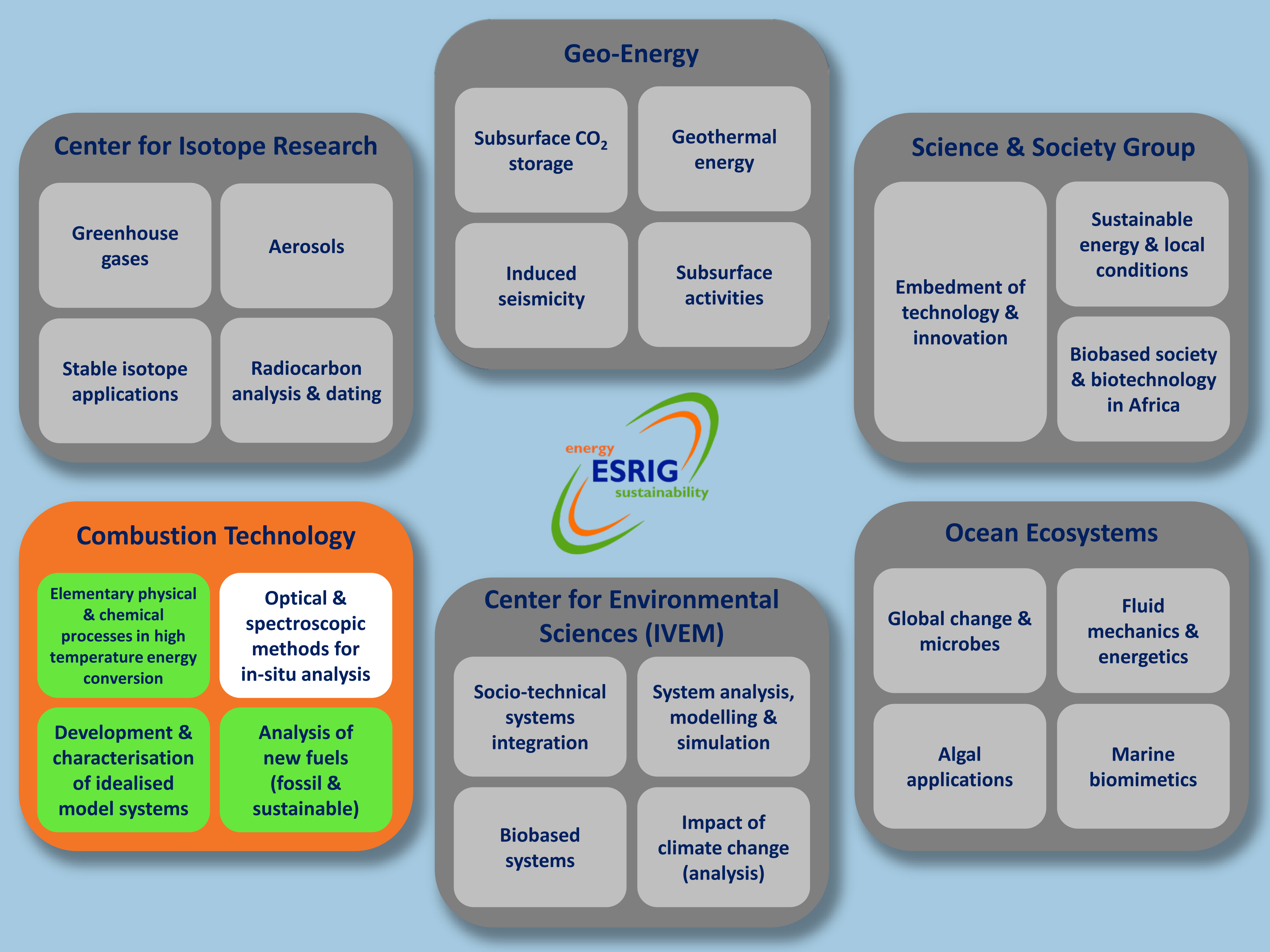
- Elementary physical & chemical processes in high temperature energy conversion
- Optical & spectroscopic methods for in-situ analysis
- Development & characterisation of idealised model systems
- Analysis of new fuels (fossil & sustainable)

Center for Environmental Sciences (IVEM)

- Socio-technical systems integration
- System analysis, modelling & simulation
- Biobased systems
- Impact of climate change (analysis)

Ocean Ecosystems

- Global change & microbes
- Fluid mechanics & energetics
- Algal applications
- Marine biomimetics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Laser Diagnostics of Particles in Gas Flames

Peter N. Langenkamp

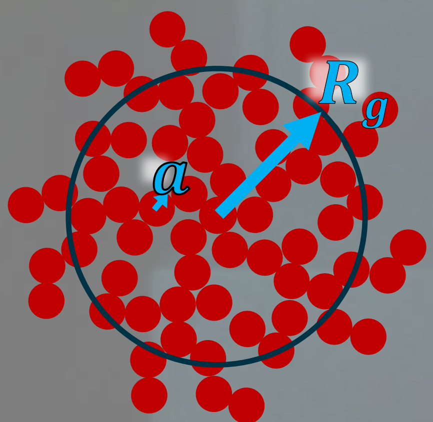
Combustion Technology

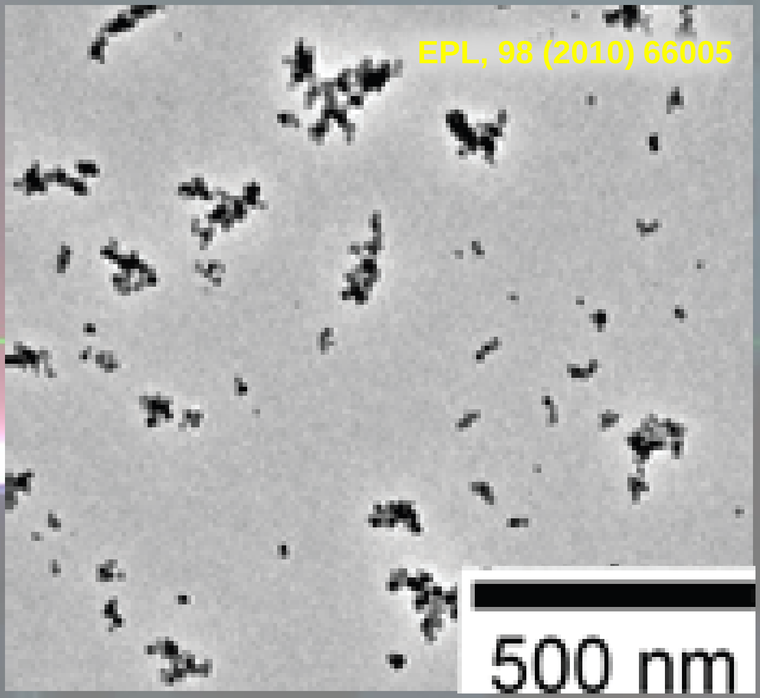
ESRIG Symposium 2018

university of groningen

What kind of particles?

- Soot (fuel-rich hydrocarbon flames)
- Silica (e.g. from trace compounds in biogas)

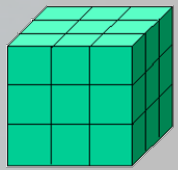




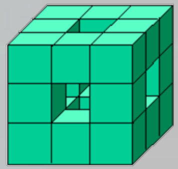
$$N = k_0 \left(\frac{R_g}{a} \right)^{D_f}$$

N	Number of clusters in aggregate
k_0	Proportionality constant
R_g	Radius of Gyration $= \sqrt{\frac{\sum m_i r_i^2}{\sum m_i}}$
a	Radius of monomers
D_f	Fractal dimension

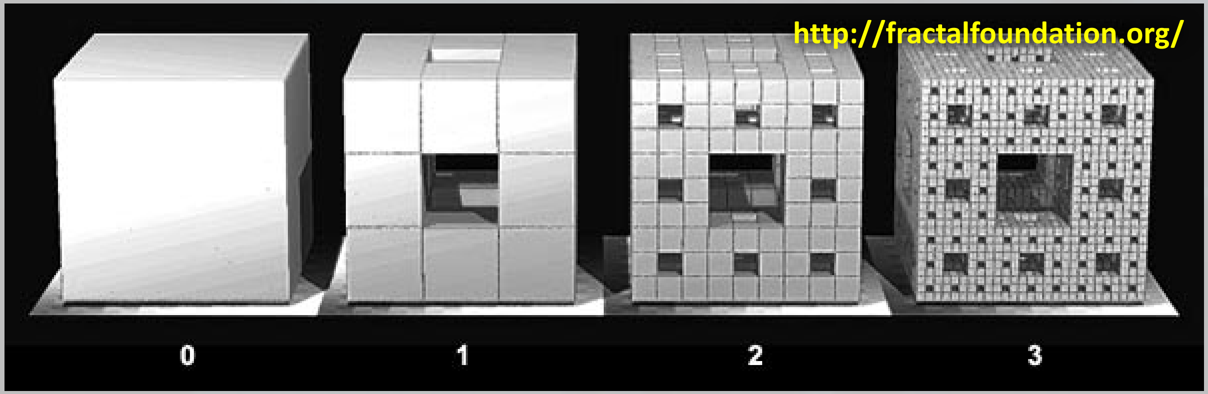
Fractal dimension



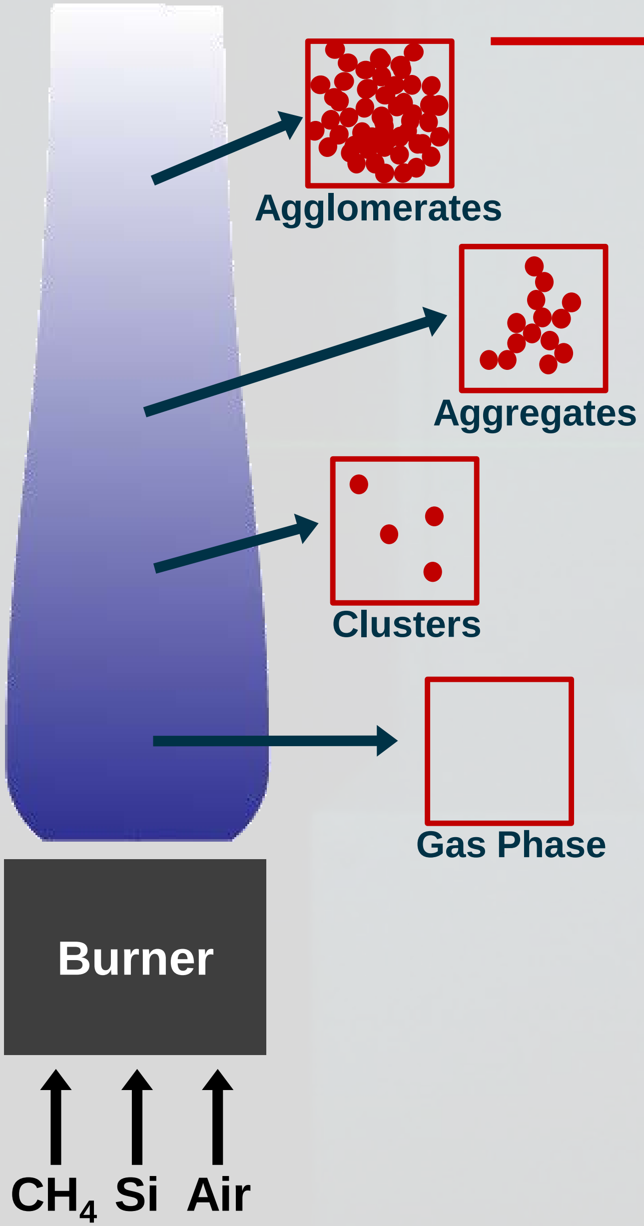
Magnification : ×3
Number of cubes: ×27 } $\Rightarrow \; 3^{D_f} = 27 \;\Rightarrow\; D_f = 3$



Magnification (scale of outer dimensions): ×3
Number of cubes: ×20 } $\Rightarrow \; 3^{D_f} = 20 \;\Rightarrow\; D_f = 2.7$



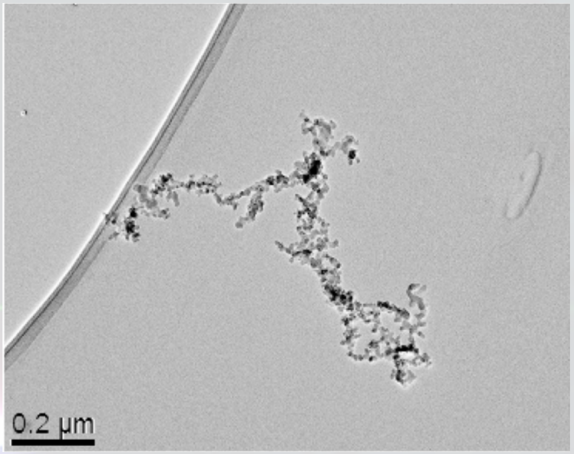
Growth of particles



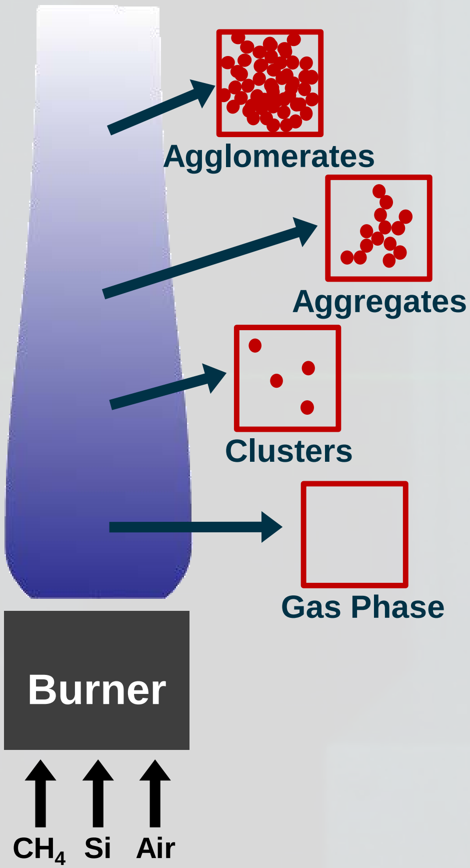
- Aggregates agglomerate into 1 – 10 µm particles
- Clusters collide, forming larger (≈ 100 nm) fractal-like aggregates
- SiO_2 particles collide, forming 1 – 10 nm clusters
- In combustion Si containing compounds rapidly form SiO_2

Why are we interested?

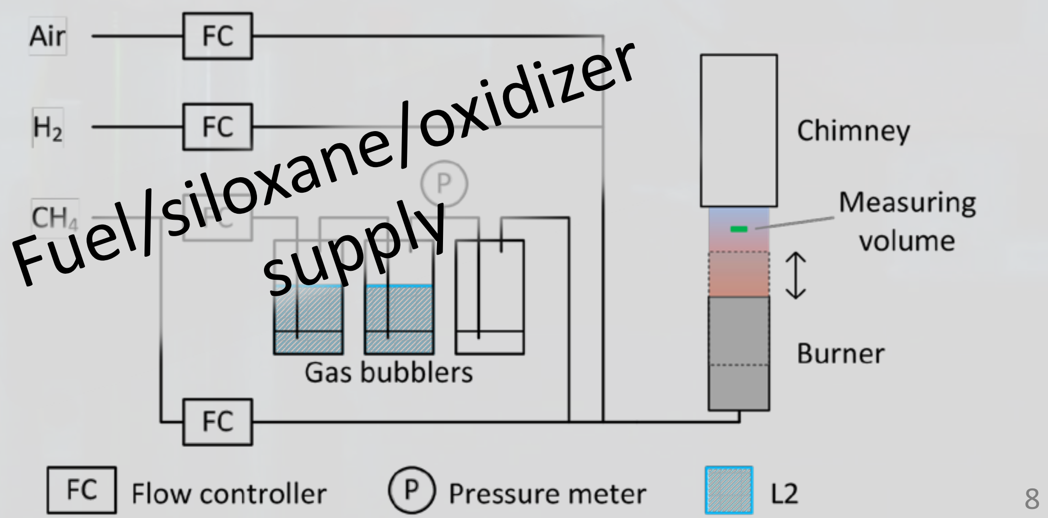
- Improve models
- Particles are harmful to
  - Health
  - Environment
  - Combustion equipment
- Possible applications
  - Aerogel
  - Catalyst
  - Filter



Investigating particles formed in flame

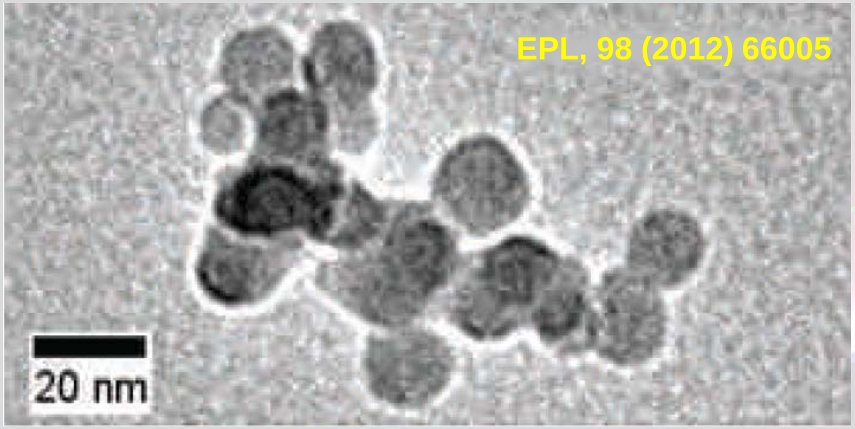


- Evolution in time (range of heights above burner)
- Effect of hydrogen fraction in fuel
- Different flame conditions (flame T, equivalence ratio)



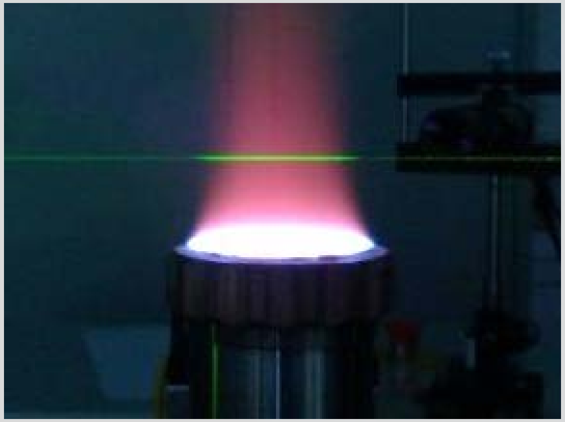
Why Laser Diagnostics?

- Transmission electron microscopy (TEM)



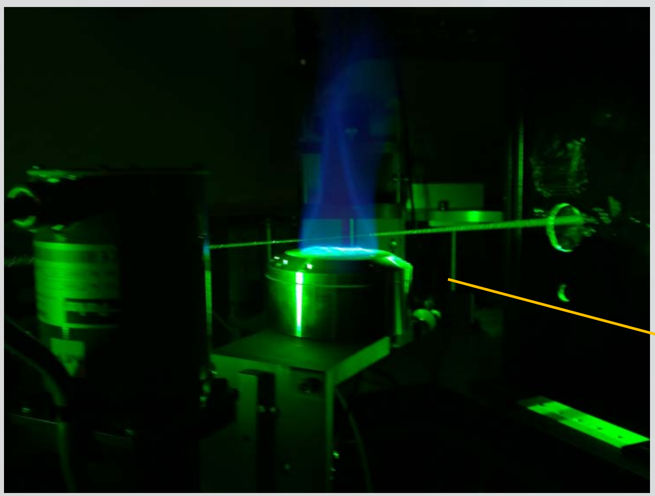
  - Individual particles
  - Time consuming
  - Sampling disturbs system

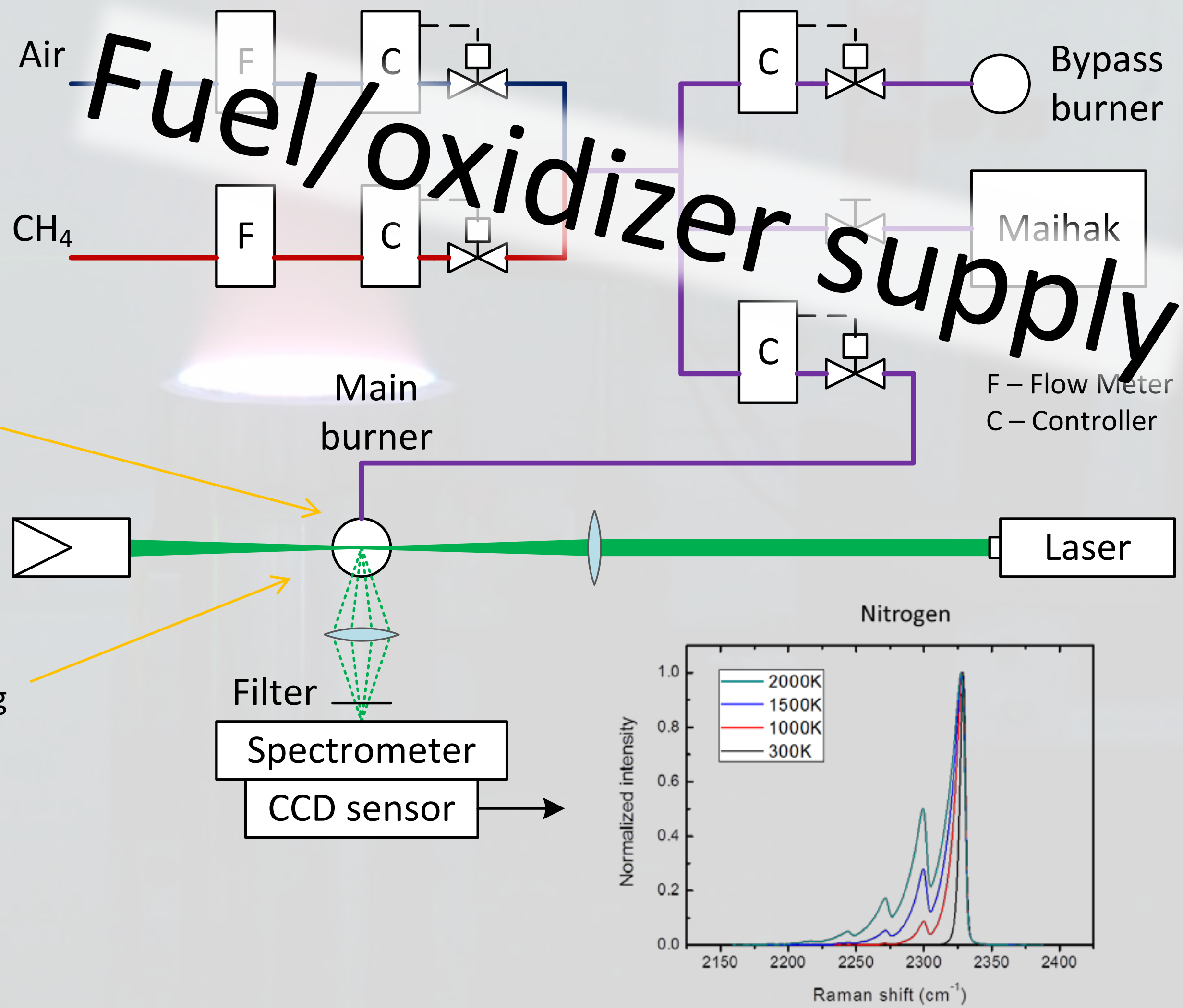
- Laser light scattering (LLS)



  - Average of particles
  - Immediate information
  - No disturbance of the flame

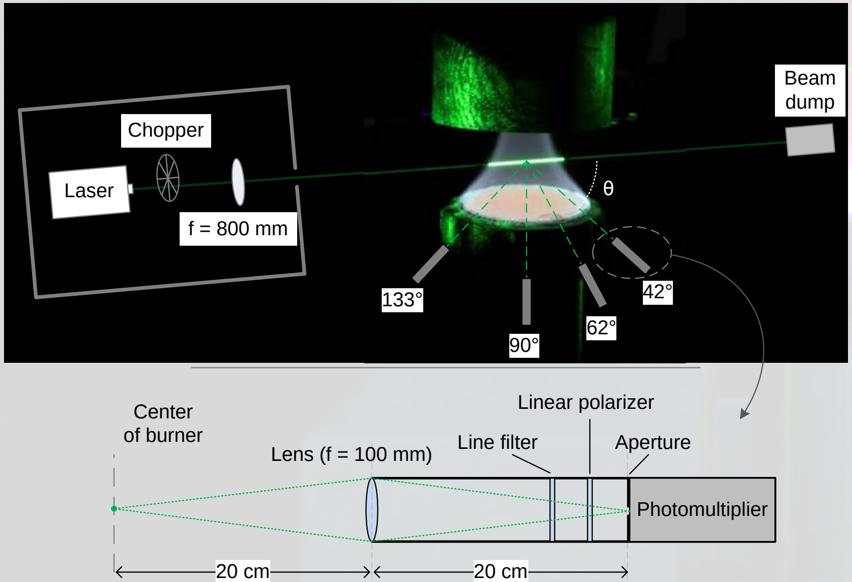
From flame to temperature



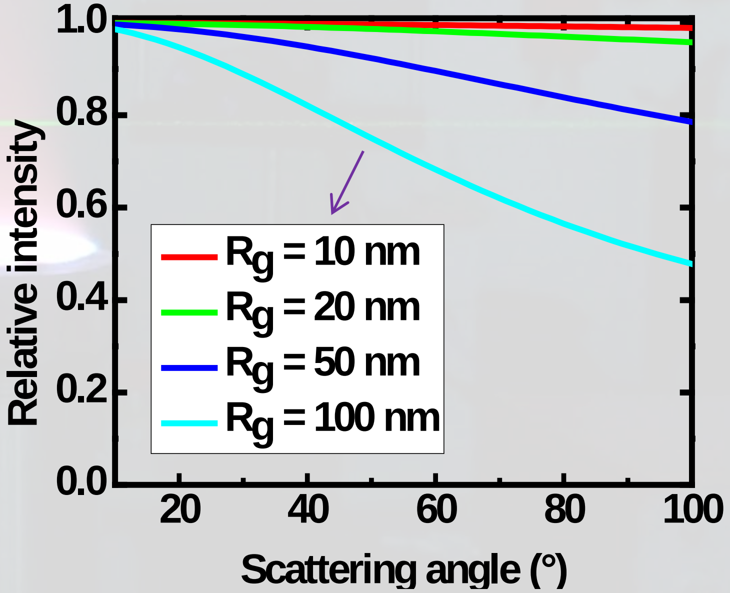


Measuring particle size

Angle dependent light scattering

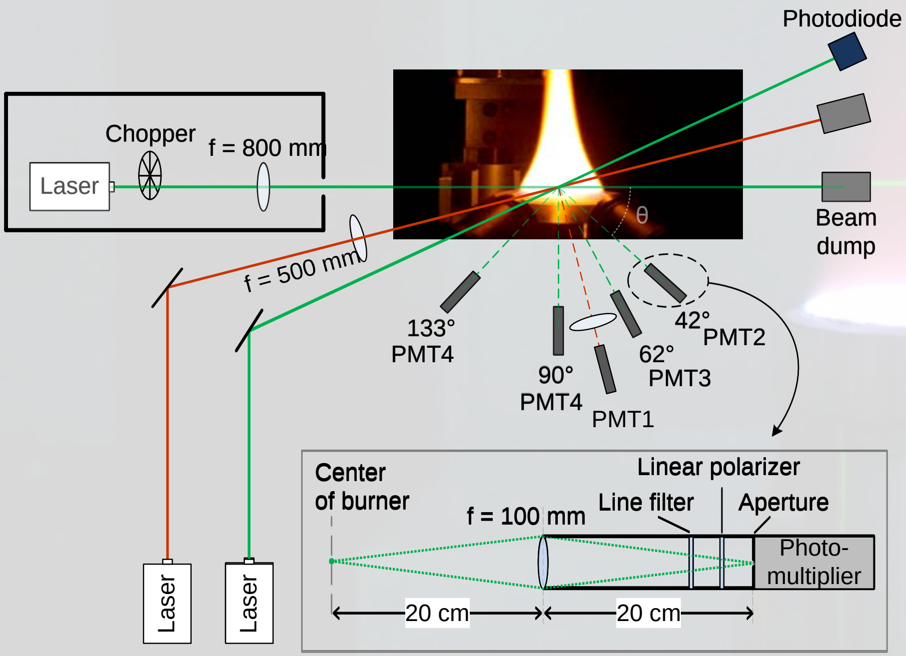


Guinier analysis



- Challenge: small differences for small particles

Measuring soot volume fraction



- Laser Light Extinction
  - Decrease in laser intensity → volume fraction
- Laser-Induced incandescence (LII)
  - Laser heats up particles
  - Signal from hot particles proportional to volume fraction

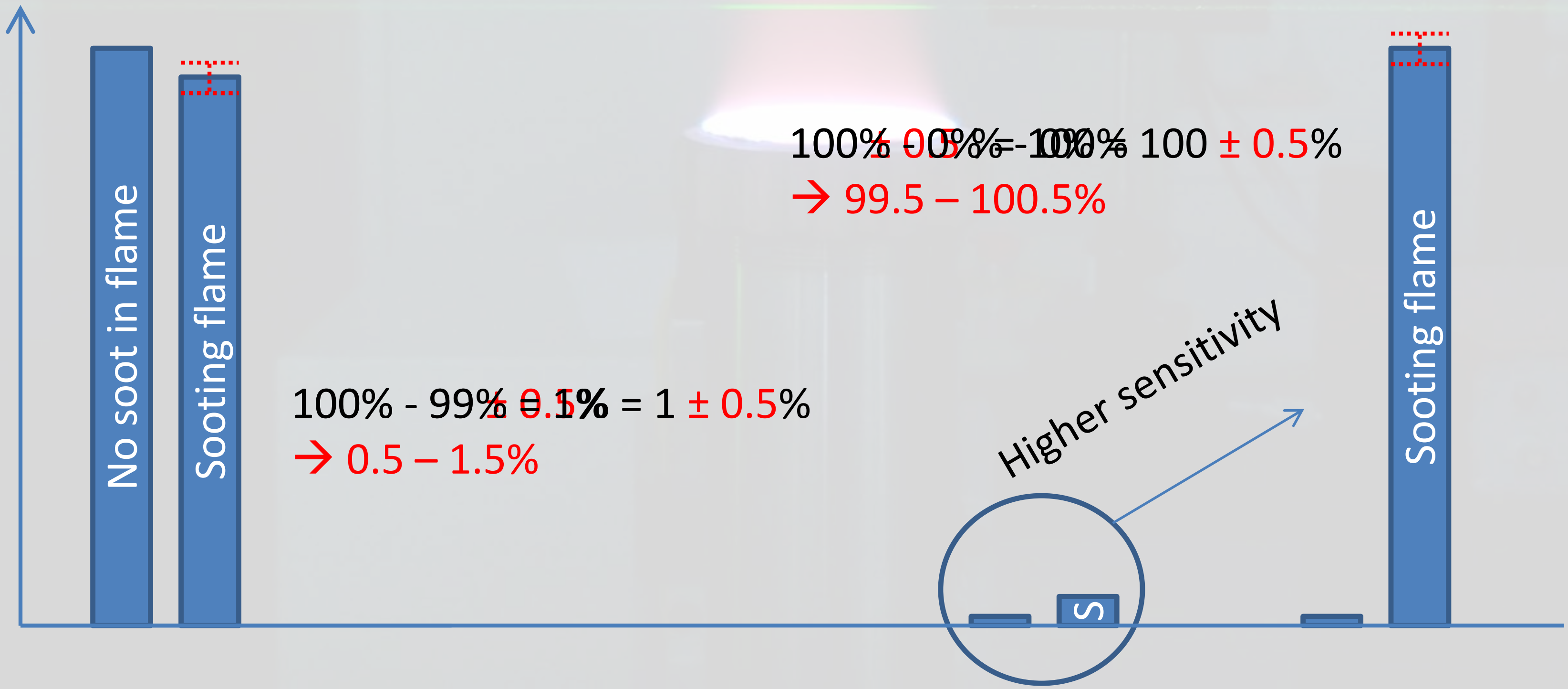
Extinction vs. LII

Laser Light Extinction

- No need for calibration
- Low sensitivity

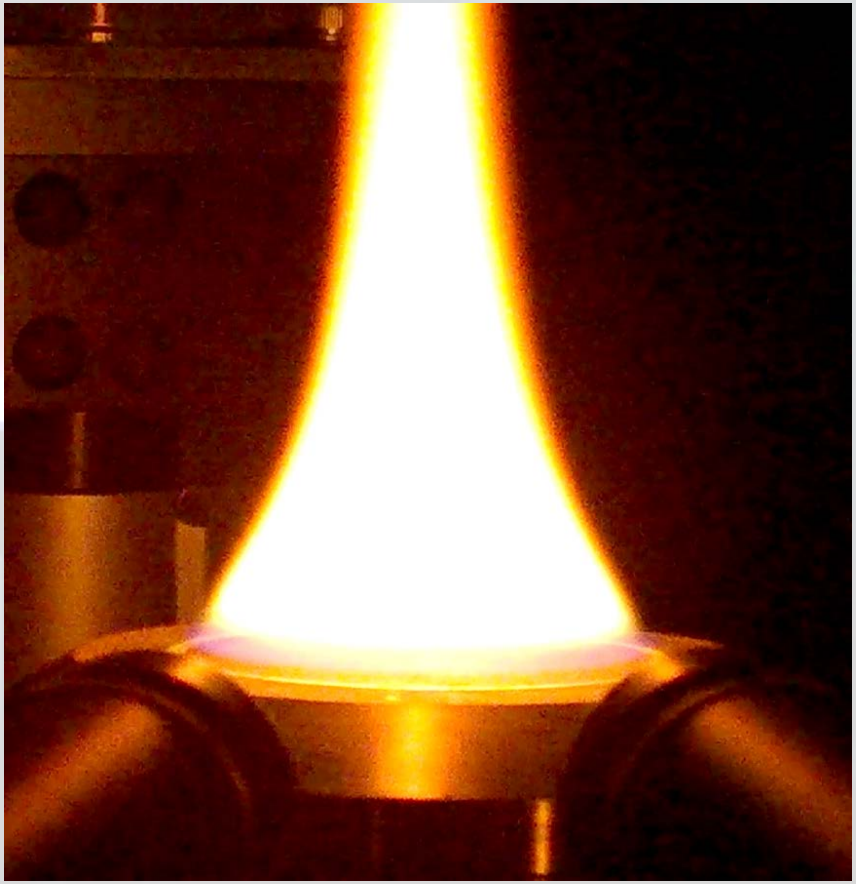
Laser-Induced Incandescence

- Requires calibration
- High sensitivity



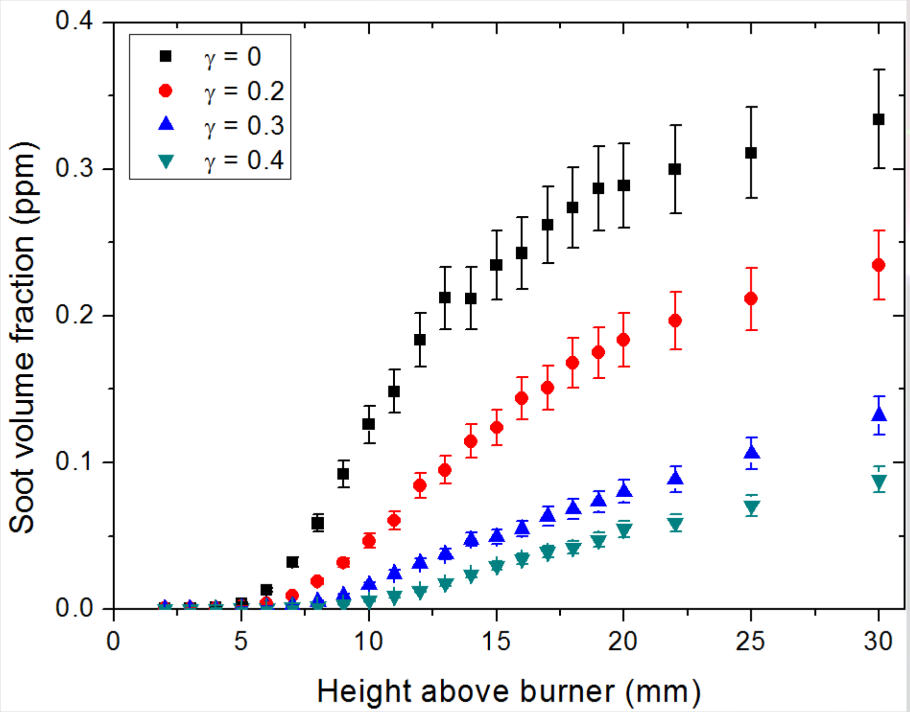
Measurements

- Fuel-rich ethylene flames produce a lot of soot
- Investigate impact of H_2 addition to fuel
- Different fuel fractions γ of H_2, compare at
  - equal fuel equivalence ratio (ϕ = 2.3) and
  - equal temperature (T = 1740 K)

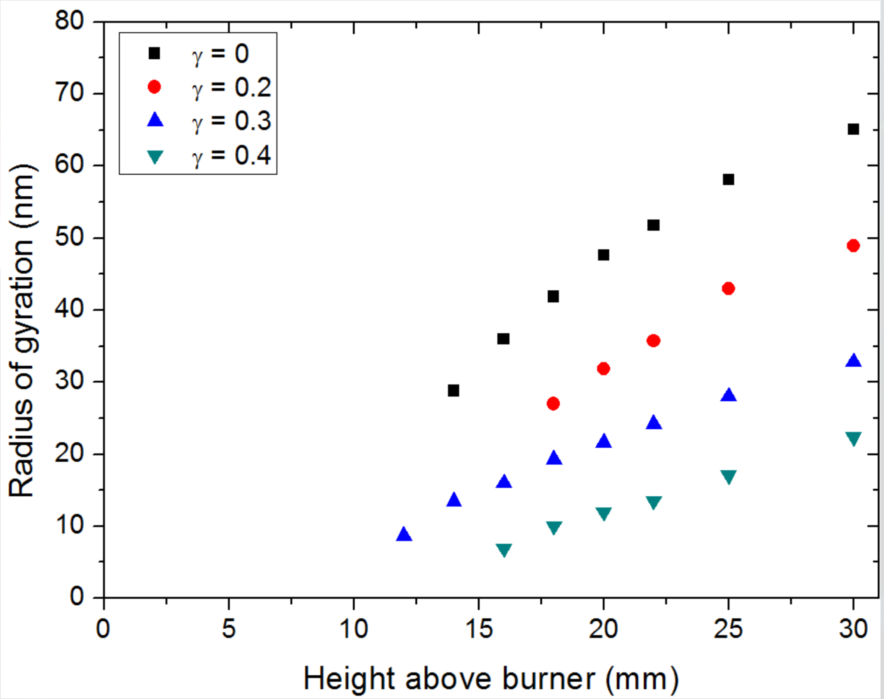


Results

Volume fraction



Radius of gyration



Questions?