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Determination of Primary Particle Size Distribution with the Laser-Induced Incandescence Soot Analyser (LI²SA)

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Principle of Laser-Induced Incandescence

Particle heating by means of a highly energetic laser pulse

Detection oft the enhanced thermal radiation with a fast detector

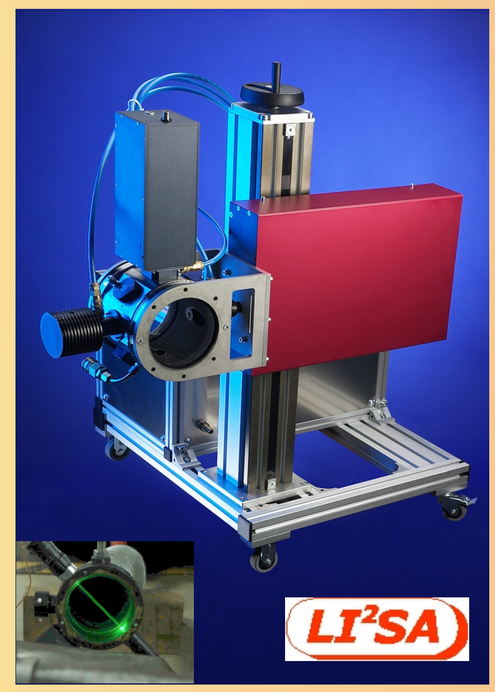
Superposition of different signal courses according to the particle collective within the measurement volume

$$\underbrace{Q_{abs}\ \frac{d_p^2}{4}\ E_i}_{Absorption} \quad \underbrace{(T\ \ T_0)\ \ d_p^2}_{Heat\ conduction} \quad \underbrace{\frac{H_v}{M}\ \frac{dm}{dt}}_{Vaporization} \quad \underbrace{d_p^2\ \ (d_p,\ )M^b(T,\ )\ d}_{Thermal\ radiation} \quad \underbrace{\frac{d_p^3}{6}\ \ s\ \ C_S\ \frac{dT}{dt}}_{Change\ of\ internal\ energy} \quad 0$$

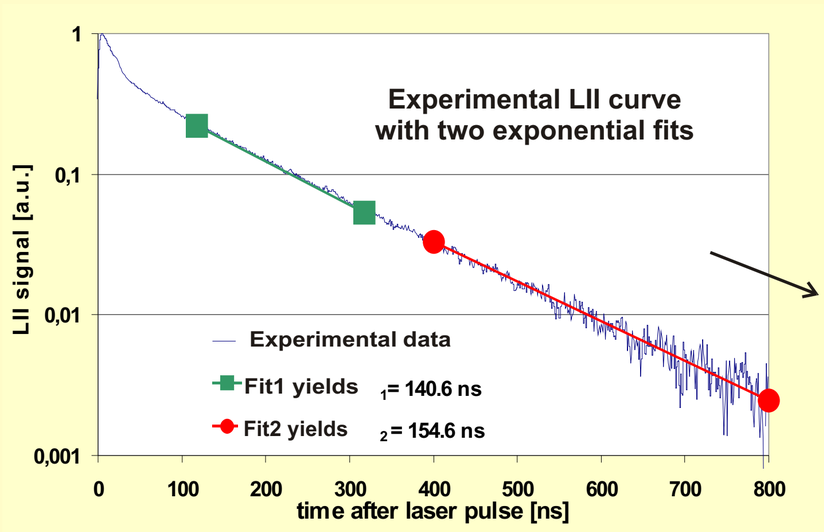
→ Numerical solution of the energy balance yields temporal signal course

→ Comparision of experimental with numerical calculated signal courses provides mean particle diameter respectively geometric standard deviation

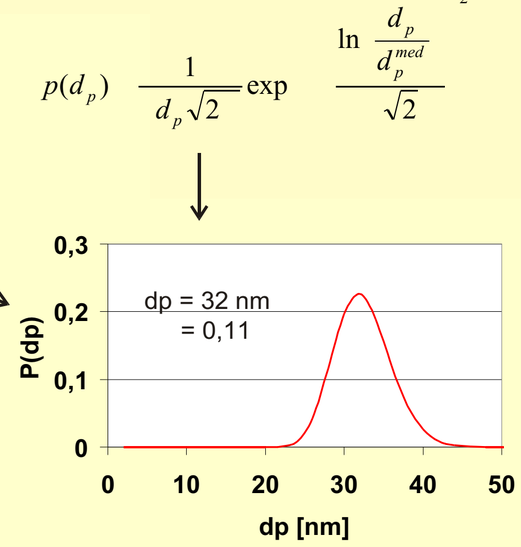
Input parameter: - Consideration of ambient temperature
- Assumption of a log normal distribution



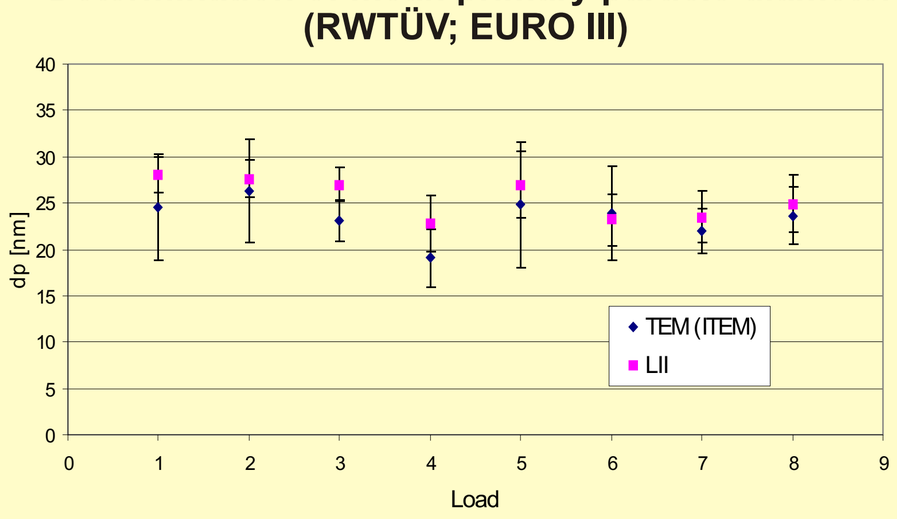
Reconstruction of primary particle size distribution



$$p(d_p)\ \ \frac{1}{d_p\sqrt{2}}\exp\ \ \frac{\ln\frac{d_p}{d_p^{med}}}{\sqrt{2}}$$

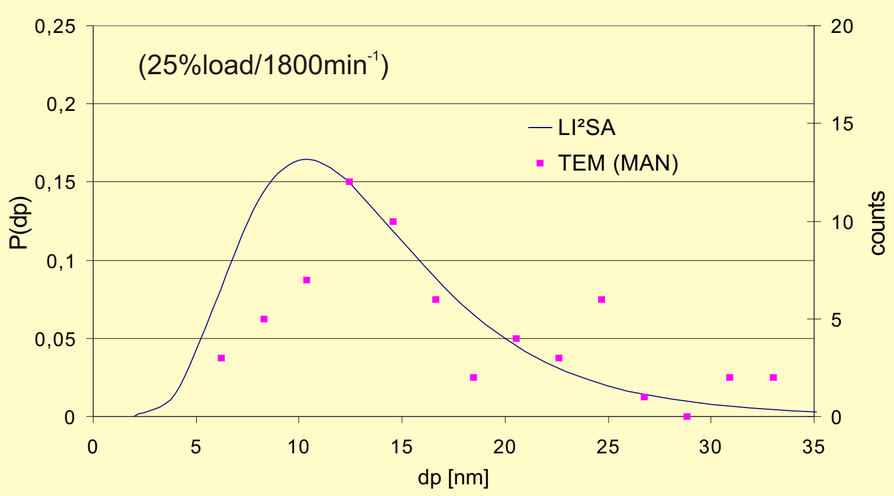


Determination of mean primary particle diameter (RWTÜV; EURO III)

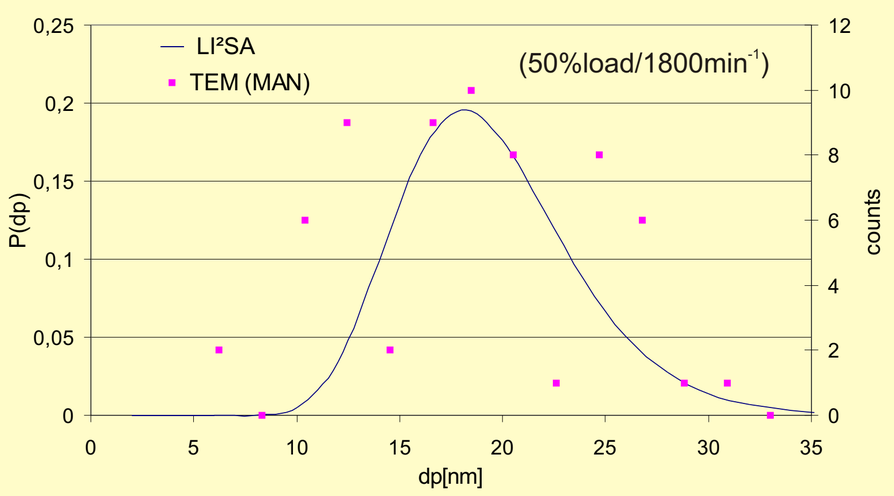


→ Good correlation beetween LII and TEM

Investigation in heavy duty diesel exhaust (MAN; EURO IV)



d_p^{med}(LI²SA)= 12,4nm = 0.43 ⟷ d_p^{med}(TEM)= 12,9nm



d_p^{med} (LI²SA) = 19nm ; = 0.22 ⟷ d_p^{med} (MAN) = 17nm

Excellent agreement despite statistical uncertainty of TEM (<100 particles)

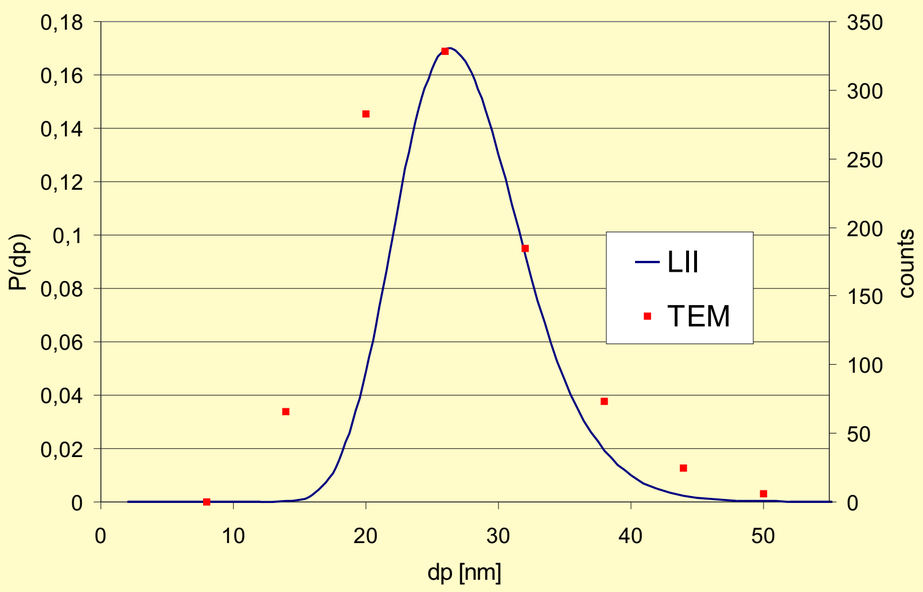
↕

particle amount (LI²SA) $5*10^{13}$ particles per m³

$6*10^6$ particles within measurement volume

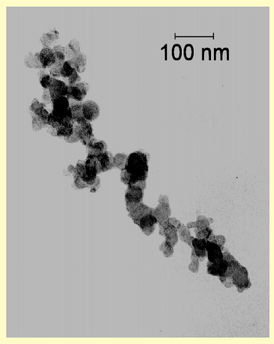
Reference: Jacob, et al., Dieselruß: Mikrostruktur und Oxidationskinetik, 24. Int. Wiener Motorensymposium 2003, Fortschritt-Berichte VDI, Reihe 12, Nr. 539, Band2, S.19-45.

Reconstruction of primary particle size distribution on carbonaceous test aerosols



LII: dp = 27,2nm; = 0,175 TEM: dp = 25,6nm; = 0,28
Degussa specification (Printex 55): dp = 25nm

→ Very good agreement between LII, TEM and carbon black specification (Degussa)



→ LI²SA is able to measure EC mass concentration (up to 20 Hz) as well as particle size distribution and mean primary particle diameter