# Modeling of time-resolved laser-induced incandescence (TIRE-LII) transients for particle sizing in high-pressure spray combustion environments

T. Dreier[1*], B. Bougie[2], L. Ganippa[2], N. Dam[2], T. Gerber[1], J. J. ter Meulen[2]
[1]Reaction Analysis Group, Department of General Energy
Paul Scherrer Institut, Villigen PSI, Switzerland
[2] Institute for Molecules and Materials, Applied Molecular Physics
Radboud University, ED Nijmegen, The Netherlands

In particle sizing in particulate laden engine combustion processes it is important to not only provide diagnostic techniques applicable for exhaust gas analysis, but also enable *in-situ* measurements in the combustion chamber under conditions of high pressure and temperature. In a comparative study we present evaluations of signal traces from time-resolved laser-induced incandescence (TIRE-LII) measurements obtained during Diesel spray combustion in a high-pressure combustion vessel as well as from an optically accessible Diesel engine. Results from three currently available LII submodels coupled with a least-squares fitting routine and a “quick-fit” interpolation are compared to retrieve ensemble mean soot particle diameters in a pressure range of 0.6-7 MPa.

## Introduction

Recently, the interest has grown in the determination of the amount and size of particulate matter during engine combustion processes due to increased emission regulation standards worldwide. In order to reduce particulate exhaust emissions in Diesel engines a better understanding of in-cylinder soot formation and destruction mechanisms is required. Partly, this task can be accomplished using non-intrusive optical techniques for the in-situ characterisation of soot properties with high temporal and spatial resolution, such as mean particle size and spatial distribution of the soot volume fraction. In laser-induced incandescence (LII) [1] particulate matter is heated to high temperatures via absorption of pulsed laser radiation, and its incandescence radiation is subsequently recorded by zero- or two-dimensional detectors. This allows temporally- and spatially-resolved in-cylinder as well as exhaust-stream diagnostics of soot. In time-resolved LII (TIRE-LII) [2] the soot particle size distribution is reflected in the recorded spectral and temporal characteristics of emitted blackbody radiation during and after laser heat-up. Therefore, TIRE-LII can be applied to retrieve ensemble averaged particle diameters in the measurement volume [3] from fitting temporal signal decays with an appropriate model function derived from the particle energy and mass balance during the heating and cooling phases.

## Models

Here, we present a comparison of several data evaluation procedures for TIRE-LII signal transients using three similar physical models currently available in the literature [4-6]. Ensemble mean particle diameters are evaluated through least-squares fitting of model functions to experimentally obtained TIRE-LII signatures. In addition, a “quick-fit” technique, recently proposed by Dankers et al. [7], reduces computational time by fitting single exponentials within two temporal windows of the LII signal trace and extracting mean particle diameters by interpolation in a pre-calculated library of decay times for a range of particle sizes and ambient pressure and temperature conditions.

## Experimental results

Experiments were conducted at pressures between 0.6 and 1.4 MPa in a high-temperature high-pressure spray combustion vessel at PSI, and at three crank angle positions in a DI Diesel engine at the University of Nijmegen, where it was shown that even at pressures as high as 7 MPa TIRE-LII signal decays still can be temporally resolved with fast photodetectors. The characteristic parameters of the various models are presented together with preliminary results of mean soot particle diameters using identical data sets obtained from TIRE-LII measurements in high-pressure Diesel spray combustion. The benefits and drawbacks of the data evaluation procedures are discussed.

## References

1 T. Ni, J. A. Pinson, S. Gupta, R.J. Santoro: Appl. Opt. 34, 7083 (1995).
2 S. Schraml, S. Dankers, K. Bader, S. Will, A. Leipertz: Combust. Flame 120, 439 (2000).
3 P. Roth, A. V. Filippov: J. Aerosol Sci. 27, 95 (1996).
4 H. Bockhorn, H. Geitlinger, B. Jungfleisch, T. Lehre, A. Schön, T. Streibel, R. Suntz: Phys. Chem. Chem. Phys. 4, 3780 (2002).
5 T. Schittkowski, B. Mewes, D. Brüggemann: Phys. Chem. Chem. Phys. 4, 2063 (2002).
6 B.F. Kock, T. Eckhardt, P. Roth: Proc. Combust. Inst. 29, 2778 (2002).
7 S. Dankers, A. Leipertz: Appl. Opt. 43, 3726 (2004).

* Corresponding author: thomas.dreier@psi.ch
Proceedings of the International Bunsen Discussion Meeting 2005: Laser-induced Incandescence, Quantitative interpretation, modelling, application