



HAL
open science

Laser-induced incandescence and fluorescence for in-situ characterization of soot particles and precursors in semi-technical aeronautic combustors

Jean-Pierre Dufitumukiza, Cornélia Irimiea, Klaus Peter Geigle, Zhiyao Yin, Axel Vincent, Nicolas Fdida, Rafael Barrellon-Vernay, Arnaud Ristori, Pascal Cherubini, David Carru, et al.

► To cite this version:

Jean-Pierre Dufitumukiza, Cornélia Irimiea, Klaus Peter Geigle, Zhiyao Yin, Axel Vincent, et al.. Laser-induced incandescence and fluorescence for in-situ characterization of soot particles and precursors in semi-technical aeronautic combustors. Journée François Lacas 2021 - Journée des Doctorants en Combustion, Jan 2021, Virtuel, France. hal-03130511

HAL Id: hal-03130511

<https://hal.science/hal-03130511v1>

Submitted on 3 Feb 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Laser-induced incandescence and fluorescence for in-situ characterization of soot particles and precursors in semi-technical aeronautic combustors

J.P. Dufitumukiza^{1,2}, C. Irimiea¹, K.P. Geigle³, Z. Yin³, A. Vincent¹, N. Fdida¹, R. Barrellon-Vernay^{1,4}, A. Ristori¹, P. Cherubini¹, D. Carru¹, D. Gaffié¹, X. Mercier² and A. K. Mohamed¹

¹DMPE, ONERA, Paris-Saclay Univ., Palaiseau, 91120, France

²Lille Univ., CNRS, PC2A, Villeneuve d'Ascq, 59655, France

³German Aerospace Center, Stuttgart, 70569, Germany

⁴Lille Univ., CNRS, PhLAM, Villeneuve d'Ascq, 59655, France

Keywords: Laser induced incandescence/fluorescence, aeronautic combustor, soot, soot precursors.

Presenting author email: jean-pierre.dufitumukiza@onera.fr

Physical and chemical properties of soot emitted from airplanes are still poorly known due to the difficult access at the core of these systems, as well as the stringent conditions into or at the exhaust of the engines. It is challenging to directly measure soot particles inside aeronautic combustors due to the high pressure and limited optical access. Under these harsh combustion conditions, we try to identify the mechanisms participating in the formation of soot particles. These mechanisms are still subject to numerous questions due to the lack of experimental evidence and high demand for processing power requested by theoretical models. The solution to this problem relies on the coordinated efforts of researchers for the implementation of experimental and theoretical tools.

To overcome the experimental challenges, this work focuses on the development and implementation of laser induced incandescence (LII), a technique used for the detection of soot volume fraction, as well as laser induced fluorescence (LIF), a technique used for the characterization of soot precursors.

LII and LIF techniques were implemented on the MICADO test rig to understand and evaluate the formation of soot emissions indexes in test conditions similar to single or multi-sector aeronautical engine combustors[1]. Several working points were tested, spanning the domains of pressure between 6 to 10 bars and the global equivalence ratio of the fuel between 0.7 to 0.8, with main (premixed) and pilot (non-premixed) injection of jet A-1.

In this study, two excitation laser sources have been used 1) LII at 1064 nm with a pulse duration of 7 ns and a repetition rate of 10 Hz [2] and 2) LIF at 532 nm with a pulse duration of 10 ns and a repetition rate of 10 Hz. A delay of 1 μ s between LII and LIF pulses is added to avoid signal interferences. By using different optics, the Gaussian laser beams were shaped into a laser sheet of 50 mm x 0.2 mm for LII and 60 mm x 1 mm for LIF. LII and LIF detection systems are constituted of two intensified camera, objectives, and optical filters centered at 450 nm for LII and 580 nm for LIF. A dichroic mirror with a cut wavelength at 500 nm was used to direct the LII and LIF signals onto the corresponding detection systems placed at 90° one from each other.

Figure 1 illustrates an example of LII/LIF instant images obtained with the highest pressure of the combustion chamber. These results show the distribution of soot particles and precursors inside the combustion chamber near the injector. Soot precursors are localized near the injector (figure 1.a), whereas the soot particles are distributed further from the injector (figure 1.b).

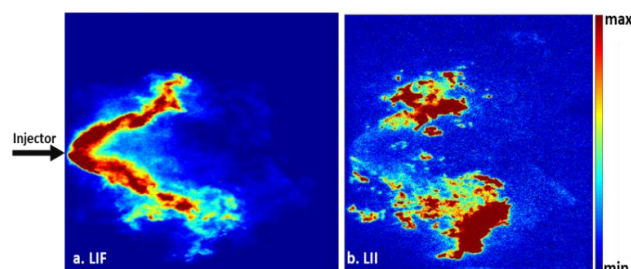


Figure 1. LIF and LII signal obtained from non-premixed kerosene jet A-1 flame, at $p=10$ bar and global equivalence ratio of 0.79. The instantaneous images of LIF (a) and LII (b) were obtained with exposure gates of 50 ns and 20 ns.

Additional working points of the combustor are discussed. There is a direct correlation between the fluorescence of polycyclic aromatic compounds and soot volume fractions detected in the combustion chamber at pressure values between 0.7 and 1 MPa. These large molecular gas-phase compounds play a crucial role in the mechanisms involved in the nucleation of soot particles and this is why their detection have high interest. The distribution of soot and precursors gives information about the evolution of the kinetics of soot at different instants and working parameters of the combustor.

Acknowledgments: This work was supported by ONERA internal project CARBON and H2020 SOPRANO project under Grant No. 690724.

References :

1. Cochet, A. *et al.* ONERA test Facilities for Combustion in Aero Gas Turbine Engines, and Associated Optical Diagnostics. *Aerosp. Lab* 1–16 (2016).
2. Geigle, K. P. *et al.* Laser-induced incandescence for soot measurements in an aero-engine combustor at pressures up to 20 bar. *Appl. Phys. B Lasers Opt.* **125**, 1–8 (2019).