CARS SPECTROSCOPY FOR TEMPERATURE MEASUREMENTS IN AIRCRAFT AND AEROSPACE COMBUSTION CHAMBERS
From ns to CPP fs CARS: An improvement of sensitivity?

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For nearly four decades, considerable efforts have been devoted to improve the design and the optimization of high performance aircraft and rocket combustors. Most of the experimental studies rely on advanced optical diagnostics which feed numerical solvers with measurements of scalar parameters. Among the optical diagnostics available thus far, coherent anti-Stokes Raman scattering (CARS) is recognized as a powerful laser diagnostic for detailed study of combustion chemistry and physics with high spatial and temporal resolutions in harsh conditions. In this study, we consider ns-CARS regime and present experimental results, then we go further with first numerical results on CARS in Chirped-Probe Pulse fs (CPP) CARS, where a picosecond probe is generated by chirping the fs pulse.

Indeed, CARS experiments are usually performed using nanosecond laser pulses to measure both gas temperature and concentrations of major species such as N_2, O_2, CO_2, CO, H_2, and H_2O. These measurements require frequency domain analysis of CARS signals, taking advantage of the direct measurement of the temperature-dependent Boltzmann-distributed population of vibrational and rotational states. To illustrate the performance of this approach, we report here the results of CARS measurements in a high-pressure gas turbine combustor facility. The multi-point injection system was operated using Jet-A fuel at inlet air temperatures up to 730 K and at combustor pressures up to 2.2 MPa for equivalence ratios ranging from 0.12 to 0.44. In these experiments, the measurements are performed with ns laser sources running at a repetition rate of 15 Hz. The resulted accuracy on temperature measurements is then noticeably depending on various parameters like the detailed knowledge of collisional energy transfer effects between the rotational lines in high-pressure and high-temperature conditions and the effect of the species composition on the interference between nonresonant background and the resonant signal.

With the recent advances of ultrafast lasers (*i.e.* ps and fs pulsed lasers), new approaches were developed to enhance the performances of CARS. For instance, the CPP *fs* CARS diagnostic is one of the most promising approaches to minimize the limitations of the ns-CARS. This technique uses pump and Stokes *fs* pulses to induce the Raman coherence of the probed molecules while a *ps* pulse is used to probe this coherence at a well suited delay. This technique then yields sufficient temporal resolution to minimize the non-resonant contributions while maintaining sufficient spectral resolution for frequency-domain detection. To study the effects of both nonresonant and collisions in the CPP *fs* CARS signal**,** a numerical code has been developed to calculate the time-resolved CPP *fs* CARS signals. The methodology used in the present work is derived from the one introduced by B. Lavorel et al. [1]. The modelling of the influence of collisions in the time domain has been performed with the well-established **G**-matrix formalism [2]. In this approach, the elements of the relaxation matrix are calculated using a classical MEG law [3]. Our aim here is to investigate parameters which have influence on the spectral shape of the CARS signal. The main parameters are pressure and temperature, but ps probe delay and pulses chirps also influence resonant to nonresonant interaction. Results on this numerical investigation will constitute the second part of the poster.

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[2] G. Knopp, P. Radi, M. Tulej, T. Gerber and P. Beaud J. Chem. Phys.**118**, pp.8223-8233 (2003) “Collision induced rotational energy transfer probed by time-resolved coherent anti-Stokes Raman scattering”
[3] J. Bonamy, *et al.* J. Chem. Phys. **94**, pp 6584 (1991) “Rotational relaxation of nitrogen in ternary mixtures N2-CO2-H2O: Consequences in coherent anti-Stokes Raman spectroscopy thermometry”