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ON RECENT PROGRESS IN PLASMA DIAGNOSTICS AND TRACE GAS DETECTION USING INFRARED LASER TECHNIQUES

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Over the last two decades chemical sensing using mid infrared laser absorption spectroscopy (MIR-LAS) in the molecular fingerprint region from 3 to 20 μm, which contains strong ro vibrational absorption bands of a large variety of gaseous species, has been established as a powerful in situ diagnostic tool for molecular plasmas and gases. Quantum cascade lasers (QCL) in particular have played a central role in this field so much so that they have become the infrared light sources of choice for plasma diagnostics and trace gas detection in the mid infrared. The methods of MIR-LAS provide a means of detecting stable and transient molecular species in ground and excited states and of measuring the concentrations and temperatures of reactive species in plasmas. Compared to “pure” trace gas detection, e.g., in environmental and combustion studies, high sensitivity is not the only issue for plasma diagnostic applications. Since kinetic processes are inherent to discharges ignited in molecular gases, high time resolution on sub second timescales is frequently desired for fundamental studies as well as for process monitoring in applied research and industry. In addition to high sensitivity and good temporal resolution the capacity for broad spectral coverage enabling multi-component detection encompassing molecules with broader absorption structures is further expanding the use of MIR-LAS techniques. QCLs possess all three characteristics required. The commercial availability of different types of distributed feedback (DFB) and external cavity (EC) QCLs along with their convenient operating conditions and performance has led to the rapid development of MIR-LAS from a niche position to a standard diagnostic technique. In the present contribution, special attention is devoted to in-situ studies of plasma chemistry and reaction kinetics in gas discharges and on selected aspects of plasma surface interactions. A link is thereby provided to modelling of plasmas and surface phenomena. Additionally, the current status of industrial process monitoring in the mid infrared is reviewed. A further increase in sensitivity to detection limits of parts-per-million (ppm) down to parts-per-trillion (ppt) levels to detect low densities of relevant species in plasmas and gases, can be achieved by combining QCLs and interband cascade lasers (ICLs) with cavity-enhanced techniques based on high finesse optical cavities.