troscopic techniques to industrial requirements. The recent development of QCLs offers an attractive new option for the monitoring and control of industrial plasma processes as well as for highly time-resolved studies on the kinetics of plasma processes.

The aim of the present contribution is threefold: (i) to review recent achievements in our understanding of molecular phenomena in plasmas, (ii) to report on selected studies of the spectroscopic properties and kinetic behaviour of radicals, and (iii) to describe the current status of advanced instrumentation for TDLAS in the mid infrared.

7222-06, Session 2

Quantum cascade laser sources and applications in trace gas sensing

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Recent advances in the development of sensors based on the use of quantum cascade lasers (QCLs) for the detection, quantification and monitoring of both small and large molecular gas species with resolved and unresolved spectroscopic features respectively will be reported. Ultra-sensitive, selective and fast response chemical analysis of gases based on molecular absorption laser spectroscopy is a well-established technology [1-4].

The architecture and performance of several sensitive, selective and real-time gas sensors based on infrared semiconductor lasers will be described. To date we have detected 17 gases (CH4, NH3, H2S, NO, N2O, CO2, CO, H2O, C2H2, C2H4, SO2, OCS, H2CO, C2H5OH, C2HF5, CH3COCH3 and C6H12O4) at the ppm to ppt level [1-4]. High sensitivity requires sensitivity enhancement schemes such as a multipass gas absorption cell, cavity absorption enhancement, or photoacoustic spectroscopy. These methods can measure absorption coefficients as low as 10-9 cm-1 for field deployable gas sensors. A novel technique called quartz-enhanced photoacoustic spectroscopy (QEPAS), which was first reported in 2002 [5-6] will be emphasized. Our progress in QEPAS optimization has now resulted in a 60 fold increase in detection sensitivity as a result of incremental improvements in optical coupling, acoustic design and electronics. QEPAS allows a breakthrough in size, weight, robustness and cost as well as wireless sensor network nodes [7] for laser-based chemical sensing applications. Applications include the monitoring of single and multiple gas species for applications in such diverse fields as in environmental monitoring, industrial process control, medical diagnostics and homeland security [2-4]

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7222-07, Session 2

Hot electron effects and nanoscale heat transfer in Terahertz quantum cascade lasers

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In electronic and photonic devices the equilibrium between the input power and the energy loss rate is reached at electron average energies larger than the crystal lattice one. The associated non-equilibrium, or so-called hot-electron distribution of high-energy carriers may deviate significantly from Fermi-Dirac or Maxwell-Boltzmann statistical functions. However, when the electron-electron (e-e) interaction dominates over other scattering processes, a thermalized electronic distribution, characterized by an effective temperature (Te) larger than the lattice one (TL) is established. This case is quite common in most devices, where high enough electron densities larger than 109 cm-2 are present and the e-e scattering rates fall in the sub-picosecond regime, thereby being faster than e-phonon or e-defect interactions.

In quantum device structures based on two or more electronic subsystems, due to the existence of different energy exchange channels, electronic ensembles characterized by different temperatures may exist. Among these systems, quantum cascade lasers (QCLs) can be considered as a prototype. Because of the large electrical power deposited into the active region, the limited e-lattice relaxation efficiency and the inherent high thermal resistance associated with their multilayered structure, QCL devices are especially prone to hot-electron effects.

In this work we report an experimental study of the correlation of the electronic temperature of the active region with the stimulated emission of photons in QCLs. Using micro-probe photoluminescence (PL) we report the evidence of a new physical phenomenon characteristic of semiconductor lasers, i.e. the cooling of the electrons above the laser threshold for stimulated emission. This effect is directly related with the quantum efficiency, which is one of the central physical quantities in the theory of semiconductor lasers. As a model system we have selected the terahertz quantum cascade laser, in which hot-electron effects must be fully understood to explore the device physical limits in terms of maximum temperature, wavelength and quantum efficiencies.

Furthermore by means of time resolved PL experiments we explore the heat propagation velocity in the individual epilayers of THz QCL devices, exploring the advantages of the waveguide and processing geometries in the thermal management of QCLs.

Finally, the possibility of generating stimulated emission of phonons in terahertz quantum cascade lasers will be also discussed.

7222-08, Session 3

Application of quantum cascade lasers for infrared spectroscopy of jet-cooled molecules and complexes

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The combination of infrared laser spectroscopy with a molecular jet expansion is a powerful technique to investigate medium sized organic molecules and their molecular clusters. Because of the high energy level densities of these relatively large molecular systems, it is essential to have a highly sensitive infrared spectrometer for their spectroscopic studies. In addition, it is high desirable to have simple and robust designs so that such a spectrometer can be used routinely with little maintenance.

We have designed and constructed three different infrared spectrometers coupled with a pulsed molecular jet assembly. These are: a cavity ring down spectrometer [1], a rapid scan spectrometer with multi-pass cell with astigmatic mirrors [2], and an off-axis cavity enhanced absorption spectrometer [3]. Two types of quantum cascade lasers (QCL) are utilized as the infrared laser sources. One of them is a continuous wave (cw) liquid nitrogen cooled