

Abstract

A sensitive detection of specific atoms and molecules in the gas phase is very important for many applications, such as environment analysis, clinical diagnostics, optimization of combustion processes and industrial process monitoring. Diode pumped fiber lasers with a broadband emission spectrum, a compact design and a low power consumption are very suitable for the construction of sensitive analysers for the gases placed inside their cavity. Intracavity absorption spectroscopy (ICAS) is a very sensitive technique for the detection of optical absorption. The sensitivity of ICAS corresponds to conventional absorption measurements with an effective absorption path length, which can extend up to several thousands kilometres. The present work deals with the application of various multimode fibre lasers for ICAS and identification of the mechanisms limiting their sensitivity to intracavity absorption.

The detailed investigations of the Nd³⁺-doped fibre laser with atmospheric absorption inside the cavity have shown that the most important mechanisms limiting the sensitivity of ICAS are the Rayleigh scattering and the spatial inhomogeneity of the gain. The sensitivity reached with this Nd³⁺-doped fibre laser in the spectral range 1,08-1,12 μm corresponds to the effective absorption path length of $L_{\text{eff}} = 40$ km. An enhancement of the sensitivity can be achieved by the reduction of the influence of both mechanisms. The Rayleigh scattering can be reduced e.g. by utilizing the fibers with a smaller numerical aperture, reduced scattering rates and a smaller length. The spatial inhomogeneity of the gain can be reduced by the proper choice of the laser parameters and completely suppressed by the use of a ring cavity configuration. In this case the effective absorption path length can be increased up to several thousands kilometres.

An application of Er³⁺-doped multimode fibre lasers emitting in the infrared spectral region 6200-6550 cm^{-1} (1,52-1,61 μm) to ICAS has been demonstrated for the first time. The achieved sensitivity corresponds to the effective absorption path length of $L_{\text{eff}} = 54$ km. Due to a good quality of an Er³⁺-doped telecommunication fibers the achieved sensitivity is ten times higher than it has been reached with a Tm³⁺-doped fibre laser emitting in the neighbouring spectral range (1,7-1,8 μm). The detection limit of 60 ppb has been demonstrated with the measurements of acetylene (C₂H₂) inside the laser cavity. Other gases such as carbon dioxide (CO₂) and carbon monoxide (CO), which are important for the environment monitoring, have been also detected inside the cavity with a high sensitivity. The selective measurements on the isotopes ¹²CO₂ and ¹³CO₂, which are important for the clinical diagnostics of human breath, have been also performed. The chemical dynamics of the combustion products HCN and NH₃ in a low pressure flame has been observed for the first time by *in situ* absorption measurements inside the laser cavity.

The possibility of application of microstructured fiber lasers for the sensitive absorption spectroscopy of the samples inside the fiber holes within the evanescent field of the multimode laser has been investigated. It has been shown, that in order to perform a sensitive detection of nano samples inside the holes, the spectral loss modulation due to the interference of the laser light reflected from the holes must be suppressed, e.g. by the application of the fibers with an irregular hole-cladding structure.