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Simultaneous frequency stabilization of four laser diodes in the 935-nm water vapour spectrum for space application

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Water vapour is a major atmospheric gas in terms of impact on climate and weather. Since its highly variable distribution in time and space is not covered satisfactorily with current instruments, improved water vapour measuring systems with global coverage are strongly demanded by the user community. For this reason, the European Space Agency (ESA) has been planning a satellite-borne H_2O differential-absorption lidar (DIAL) instrument. The DIAL technique offers high vertical resolution and selective gas detection by sensing the difference in light absorption at two close on-line and off-line wavelengths.

In the frame of an ESA-ESTEC supported study, we are developing a frequency detection unit (FDU) delivering four stable cw optical signals. They will be optically injected into the pulsed high-power oscillator of the transmitter laser, in order to set its spectral properties. This FDU is made of four injection seed lasers (ISL) precisely stabilized on four different wavelengths in the 935.4-nm range. Two different types of ISLs are used in the set-up: ECDL and DFB lasers. Three lasers are directly locked on three H_2O absorption lines of different strength, whereas the fourth laser wavelength lies outside of any absorption line (off-line wavelength). This off-line stabilization is achieved by an offset-locking technique. The FDU thus combines various stabilization schemes in order to grant an ISL stability better than 60 MHz over the 2-year expected lifetime of the system.

On-line stabilization is performed by wavelength modulation spectroscopy (WMS) using low-pressure water vapour reference cells. Due to severe ISL linewidth requirements, the laser modulation must be restricted to small values (only a few percents of the absorption linewidth). This constraint, associated to the limited optical pathlengths and H_2O absorption intensities, makes impossible the use of standard stabilization techniques based on third harmonic detection. A theoretical analysis of the WMS signals has thus been performed in order to define a suitable modulation/demodulation scheme for each ISL, as well as the cell parameters required to reach the target specifications. As a result, a balanced detection is used for the weakest H_2O line in order to remove the $1f$-background level produced by the residual laser intensity modulation. The outputs of the model will be presented and compared with experimental results. Preliminary measurements of laser stability will also be presented.

The off-line stabilization is realised by an offset-locking between two lasers. For this purpose, an electrical filter is used to create an artificial microwave absorption line which is used to lock the beat note between the two lasers at a fixed and precisely selected value. The designed method is very similar to the WMS technique used to lock a laser on a H_2O line, but it applies to the beat note in the electrical domain. Offset-locking with frequency differences up to 19 GHz has been experimentally demonstrated with the proposed technique.