InAs and InAsSbP Flip-chip LEDs for Fiber Optic Liquid Sensing in the 3-3.3 μm spectral range

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Optical transmission measurements are widely used for analysis of gases since absorption features are the «fingerprints» of most substances. These measurements are especially effective in the mid-IR spectral region (3-5 μm) where atmosphere is transparent and most gases and liquids have fundamental absorption bands.

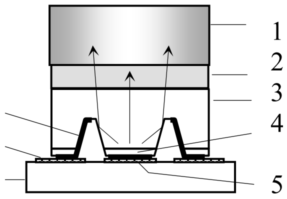

Fig.1 Scheme of a "fibre" LED, 1- optical fibre, 2- optical "glue" –chalcogenide glass (n=2.4), 3- transparent substrate or "broad band window", 4- active zone of the device (p-n junction) 5- anode connected with bonding area, 6-gold contacts (cathodes), 7- alloy – bonding areas, 8- semiinsulating silicon submount (header)

The interaction with the substance under investigation could be realized through absorption of the evanescent field in the vicinity of a fibre with the penetration depth in the outer space of the order of the wavelength. Being an elemental part of radiation traveling along the fibre axis this evanescent part is sensitive to the presence of an absorber at the fibre surface. The number of internal reflections being sufficient the output from the fibre end depends on absorber concentration and fibre length. The corresponding Fiberoptic Evanescent Wave spectroscopy (FEWS) has numerous applications including detection of flammable gases [1] and analysis of hydrocarbons in water [2, 3], however only few instruments have been reported so far that employ LED source operating in the mid-IR region. This is partly explained by low coupling efficiency due to nonoptimized constructions previously used. McCabe [1] reported the use of InGaAs LED emitting at 3.3 μm with top point contact. Direct viewing of the actived LED by a fibre coupled with InSb detector enabled to detect 1% v/v of propane at a fibre length of 23 cm. The above coupling of LED with fibre is characterized by low coupling efficiency and that's why the output power from a 1 m long fibre was in the order of 1 μW only.

Recently we reported the 3.3 μm flip-chip LEDs with the transparent substrate coupled ("glued") with the As_2S_3 fibre end. Both fibre and "glue" materials were chalcogenide glasses with very close refractive indexes and record coupling efficiency (0.3) was achieved [4]. However, the above construction could hardly be implemented into practical long lifetime FEWS liquid sensors because As_2S_3 fibre is not tolerant to water and to many other

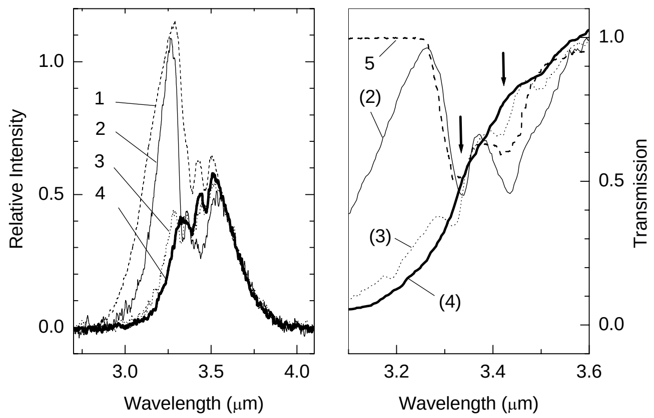

Fig.2 Emission of the 3.4 μm LED coupled with 15-cm long fibre measured at the end of the latter at the presence of air (1), alcohol (2), vodka (3) and water (4) (all at the left) and the corresponding transmission of the fiber/evanescent wave.(right) (5) – direct measurements of the alcohol vapor transmission in a 10 cm long gas cell

chemicals.

Here we report on mid-IR LEDs and first experiments on liquid sensing using sapphire fibers coupled with mid-IR LEDs emitting at 3-3.4 μm.

Fig.1 presents scheme of "flip-chip" InAs/InAsSbP double heterostructure LED whose outer layer is composed from heavily doped n^+-InAs substrate with Moss-Burstein shift of the absorption edge. Transparent chalcogenide glass with high refractive index as high as n=2.4 is sandwiched between LED and 300-μm thick Saphikon sapphire fibre without protection layers.

The ~15 cm long fiber was glued by epoxy into a 12 cm long liquid cell, filled with water or alcohol or 40% mixture of the above, that is, Vodka. The corresponding emission spectra recorded from the fibre end are shown in Fig.2 (left) together with the normalized transmission (right) defined as a ratio of the radiation intensity at liquid presence in the cell to the intensity for the empty cell. As seen from Fig.2 the fibre LED spectrum is a measure of chemical composition of the liquid since the obtained transmission matches the known features of the liquids: strong absorption at 3 μm for water and double peak absorption band for alcohol. The absorption of an evanescent wave results in the change of the far field pattern at the free fibre end that also contributes to the knowledge about the liquid absorption features as shown in Fig.3. The narrowing of beam coming from the fiber merged into the liquid is mainly attributed to the increase absorption of the evanescent wave of the rays with multiple reflections (that is, small incident angles).

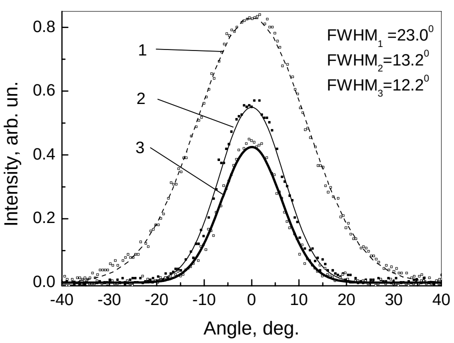

Fig.3 Far filed pattern of the 3.4 μm radiation coming from the end of the fiber merged into alcohol (2) and vodka (3), (1) – initial pattern of the radiation (without liquid)

The report will present I-U, L-I and spectral characteristics of the mid-IR InAsSbP/InAs double heterostructure, InAsSbP homojunction flip-chip LEDs emitting in the 3-3.4 μm spectral range and grown onto heavily doped n^+- InAs (111) substrates coupled with the sapphire fibers. LED constructions with two-side relief obtained through the use of two-side photolithography and microlenses made from chalcogenide glass and sapphire balls adapted for fibre optic coupling will be also described and characterized with respect to their use for fibre chemical sensing.

References

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