# MIR-fibers probe for FTIR spectroscopy at 4 - 16 um.

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## 1. INTRODUCTION

The novel practice of infrared spectroscopy in material analysis can be essentially improved using fiber accessories. Usual fiber optic feasibilities: remote control, real time monitoring, spatial resolution during fiber probe measurements (in tissue analysis) - provide a great scope for spectroscopic measurements. All these benefits stimulate a search for additional fields of fiber optic applications. Special interest is connected with fibers being transparent in middle infrared region (4um - 16 um or 2500 $cm^{-1}$ - 625 $cm^{-1}$ ), where absorption bands of most organic molecules are placed. Polycrystalline fibers, produced from solid solutions of silver halides [1] ( MIR-fibers ) are really one of the most promising candidates that can be used for spectroscopic measurements. Field of the best transmittance of MIR fibers covers all this region and their spectral characteristics are shown in Fig. 1. Tissue analysis for cancer diagnostics [2,3,6], atherosclerotic tissue diagnostics [4]; concentration measurements of the blood constituents [5] - in all these spectroscopic diagnostics methods MIR fiber can be applied. Another wide field of applications, that is mentioned in this paper, is food industry [7].

In this work only first steps in blood glucose measurements were made and possibilities of tissue analysis were demonstrated with a MIR fiber probe. Possibility for food test measurements is also have been shown.

## 2. EXPERIMENT

Two ways of fiber probe use can be considered in spectroscopic measurements. The first one is a usual absorption spectroscopy technique, and the fiber is used for the radiation delivery from source to the absorption cell and from this cell to the detector. Another way is to use unclad fiber not only for transmitting source emission, but also as detecting evanescent sensor [8]. In this case a certain section of the fiber is in contact with the medium under investigation and evanescent part of the propagating wave is absorbed in environment medium. Only the last scheme was used in our measurements.

Experimental set up is depicted in Fig. 2. Input of fiber probe is coupled to FTIR spectrometer IFS-113v "Bruker" and output is connected to MCT ( mercury cadmium telluride ) remote detector used for measurements. For the liquid solutions measurements fiber was inserted in a 1 - 4 cm long capillary tube filled by investigated substance in one case, while for tissue analysis the fiber was forced against the tissue sample. Resulting spectra were obtained

using usual routine spectra dividing technique. Spectral resolution was 4 $cm^{-1}$ for each spectrum.

## 3. RESULTS AND DISCUSSION

The results of glucose evanescent spectra measurements of aqueous solution of glucose and of the whole blood are presented in Figure 3. It is seen that in the region 1000 - 1200 $cm^{-1}$ some of the glucose absorption bands , which can be attributed to the CO-, C-O-C and C-O-H vibrations, are also revealed in the blood spectra. Absorption bands of glucose at 1040 $cm^{-1}$ and 1080 $cm^{-1}$, for example, can be found in the blood spectra. Usual water subtraction procedure wasn't made in this first qualitative analysis. During glucose solution spectra measurements 256 scans were made, and different numbers of scans were used in whole blood spectra measurements. Adsorption and desorption of blood proteins onto fiber surface during spectra measurements limited the time of measurements. It was reported that this process becomes constant within about 4 min [9].

Other series of experiments were made with tissue samples to demonstrate the possibilities of evanescent spectra tissue analysis. Fig. 4 demonstrates a set of spectra of different mouse tissues. Fiber interaction length in tissue measurements was changed from 1 cm to 4 cm. In all cases the sensitivity is enough to get tissue spectra of enough quality. This demonstrates the potentiality of remote spectroscopic measurements with fiber probe *in vivo*. The use of a short sensing part of the fiber in evanescent spectroscopy provides space resolution. Moving the sensing part of a fiber along a tissue it is possible to detect edges of the tumor. Cancer diagnostics with IR spectroscopy, including ATR technique, have been already used for the same purpose. IR spectra of normal and neoplastic tissue, presented in [3], are shown in Fig. 5.

Two examples of food industry applications are also presented. Evanescent spectra measurements of milk and beer were made and the results are presented in Fig. 6. Fat, protein and lactose from infrared absorption could be measured and fiber probe evanescent technique facilitates this procedure. Different spectra of aqueous solution of alcohol is shown on Fig.7 and could be compared with beer infrared spectra for alcohol concentration detection.

## 4. CONCLUSION

The first qualitative experiments have demonstrated the possibility of using the MIR fiber in the medical diagnostics and food industry discussed above. Some advantages of this type of fiber probe in comparison with other methods were demonstrated.

## 5. REFERENCES

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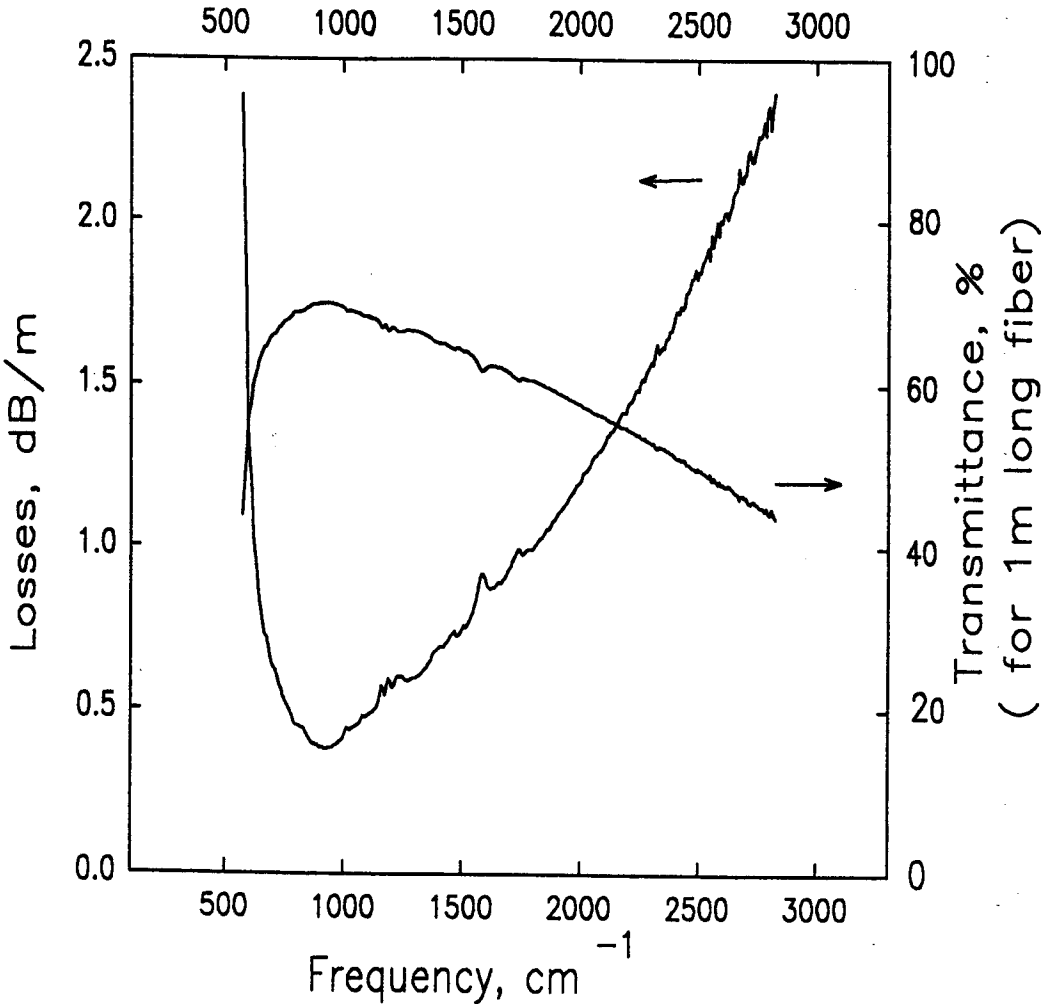



Figure 1. Spectra loss and transmittance of unclad MIR-fiber.

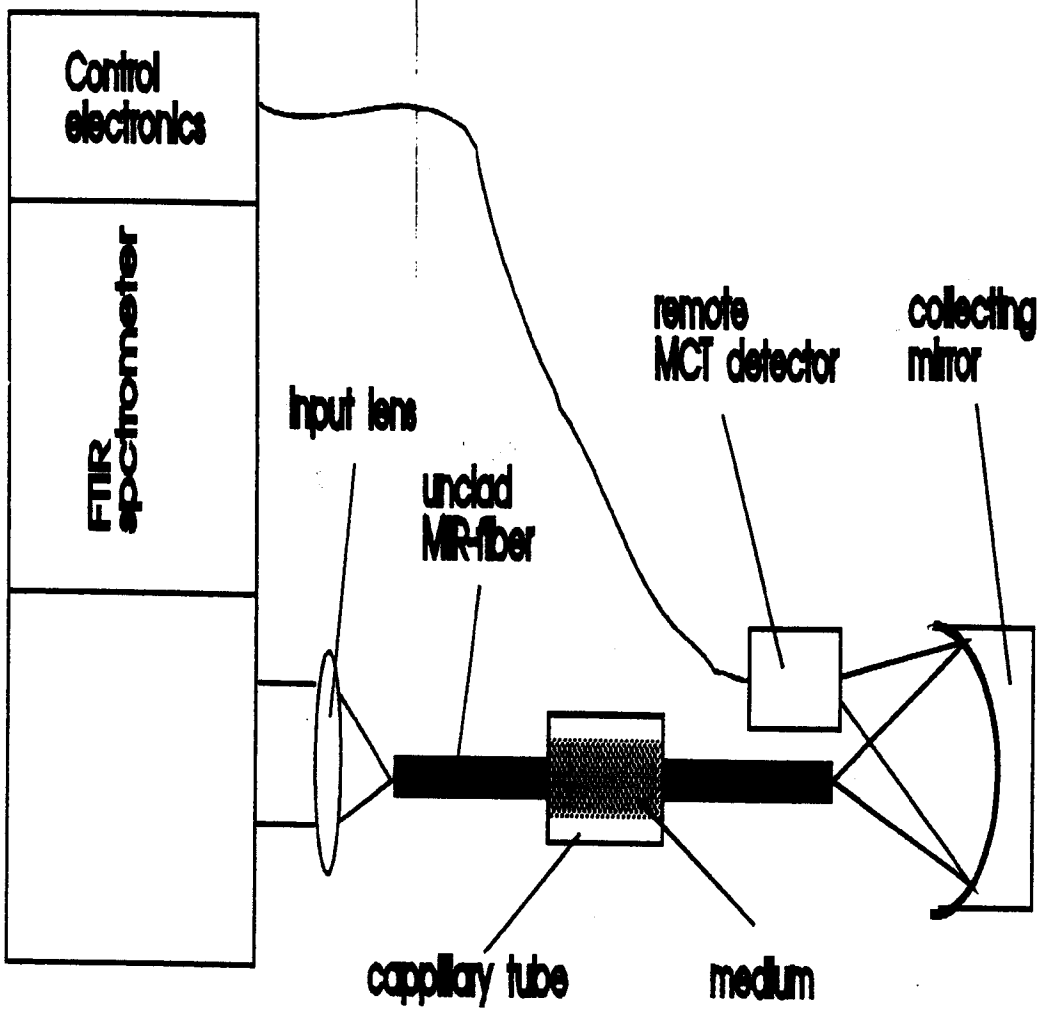



Figure 2. Experimental setup.

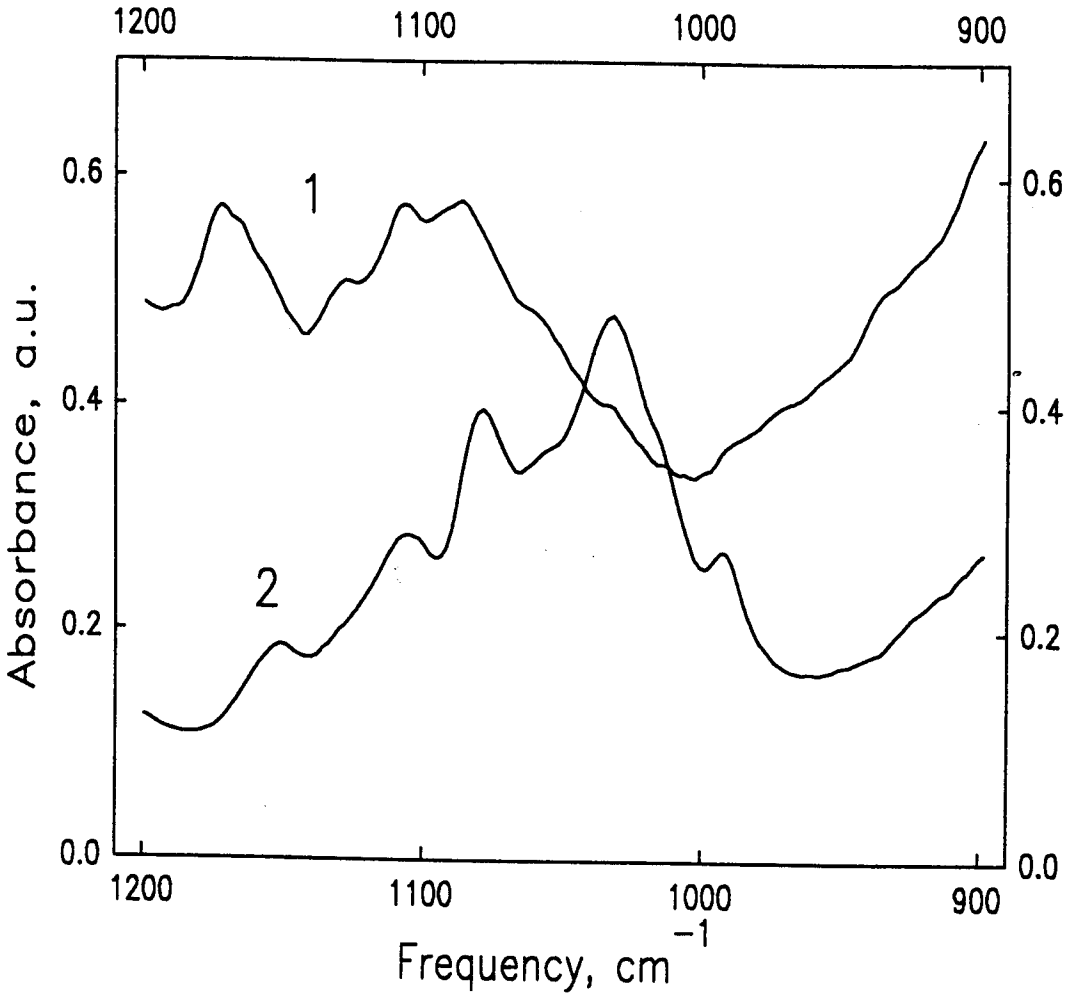
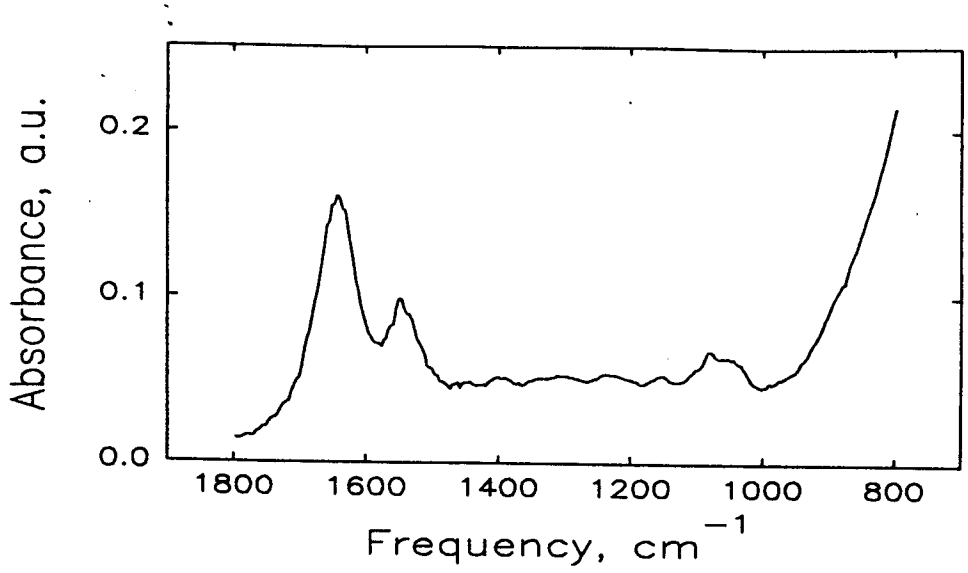
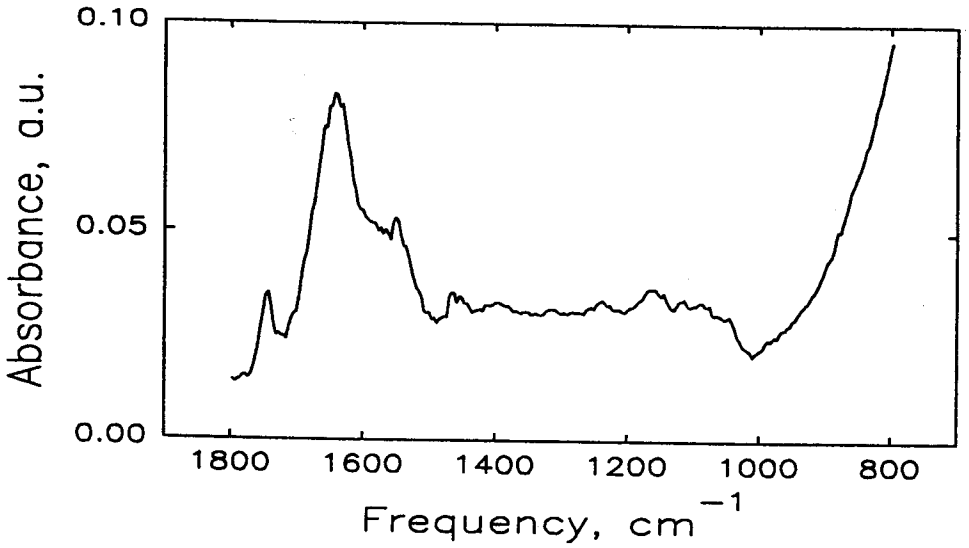



Figure 3. Evanescent spectra of whole human blood (1) and 40 % aquoeus solution of glucose (2).




a

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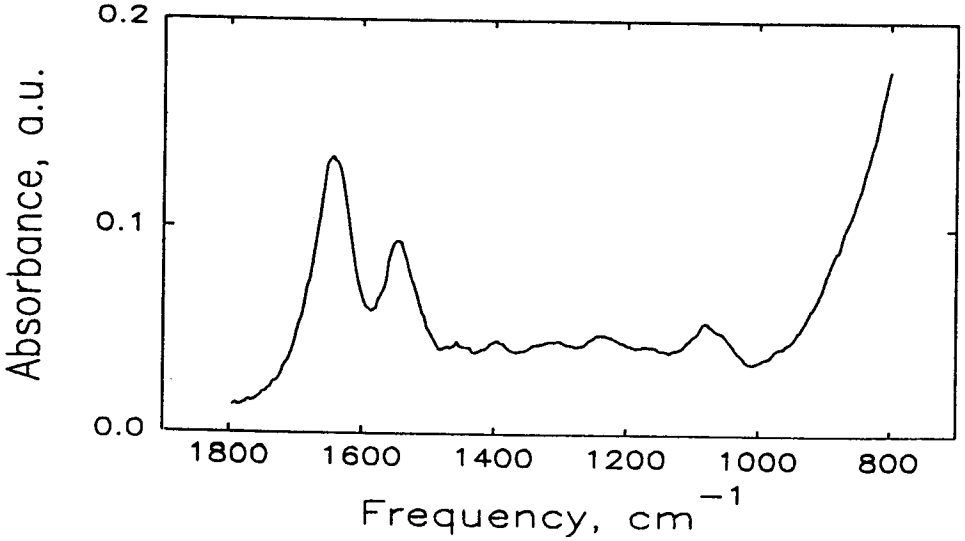


c

Figure 4 . Evanescent spectra of (a) mouse liver, (b) mouse muscular tissue, (c) mouse spleen

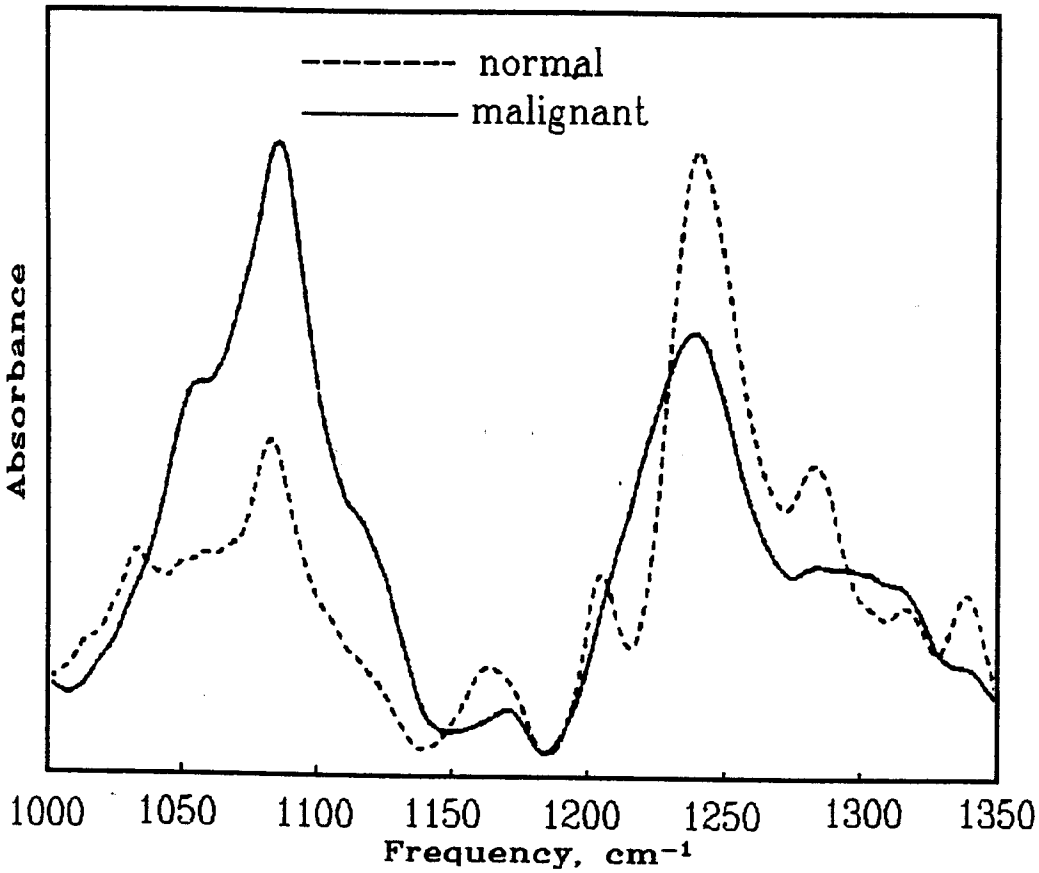


Figure.5 Infrared spectra of tissue sections from colon adenocarcinoma and histologically normal mucosa 10 cm away from the tumor [3]

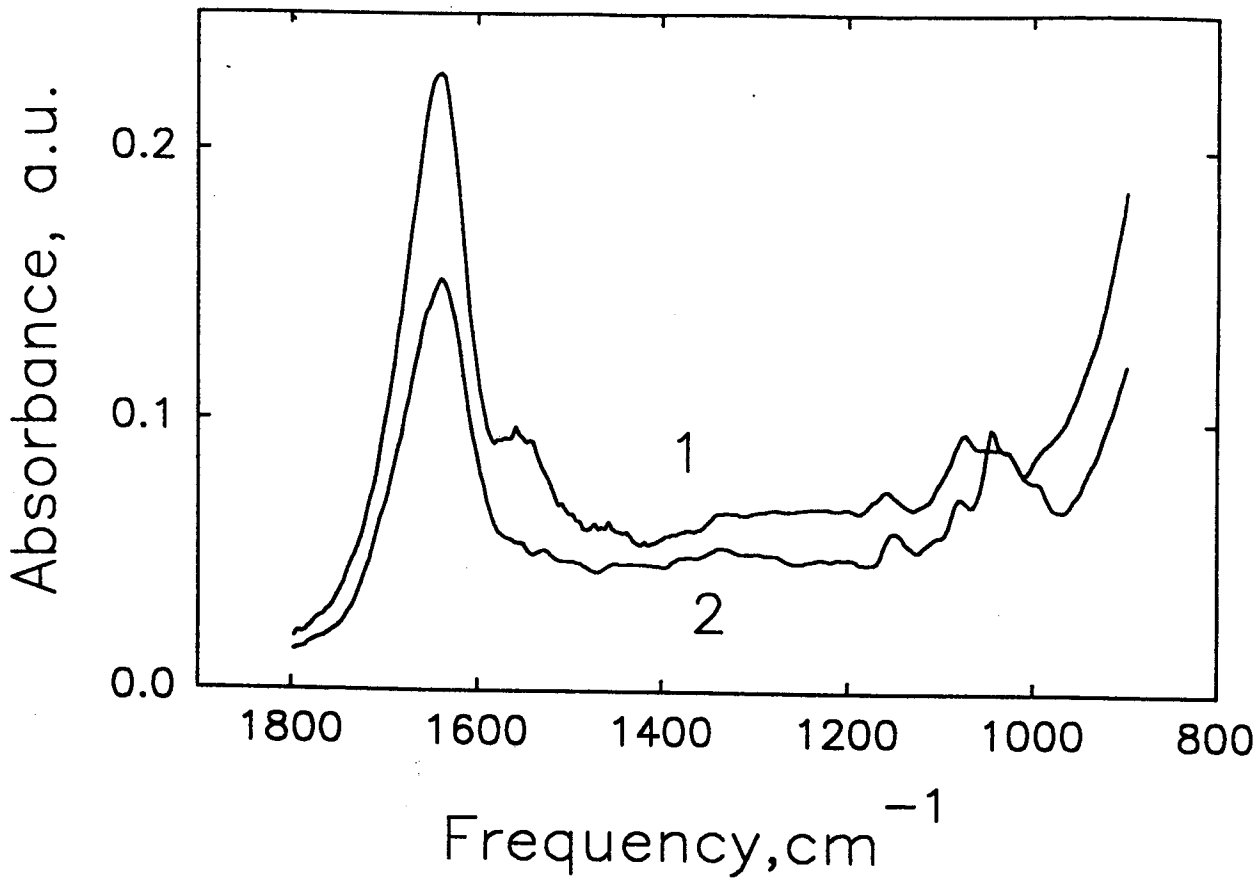


Figure 6. Evanescent spectra of milk (1) and beer (2).