Glucose concentration measurement of a transparent sample by using a Gaussian probe beam with high spherical aberration.

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Abstract: We present results of our previously reported technique based on an optical probe beam with high spherical aberration for performing glucose concentration measurements on a transparent sample. We have reported that it is possible to attain better sensitivity as compared to a system that uses a probe beam free of aberrations, under similar conditions.

1. Introduction

Many diseases are associated to abnormal glucose concentration in blood, increasing the importance of better glucose measurement systems. For improving the accuracy of these measurements, several techniques have been developed; however, in general, these techniques rely on low signal-to-noise ratios [1, 2], making it necessary to conduct further research on this subject. In a previous report, we have presented a technique based on the diffractive properties of a transmitted Gaussian probe beam with high spherical aberration that propagates through a liquid transparent sample under inspection [3]. The advantage of this technique is that it does not depend on the amplitude of a single weak signal as it is based on the profile of the probe beam that propagates through the sample. Thus, this technique is in principle immune to noise, making it more reliable.

2. Analytical description

The optical setup is depicted in Fig. 1.

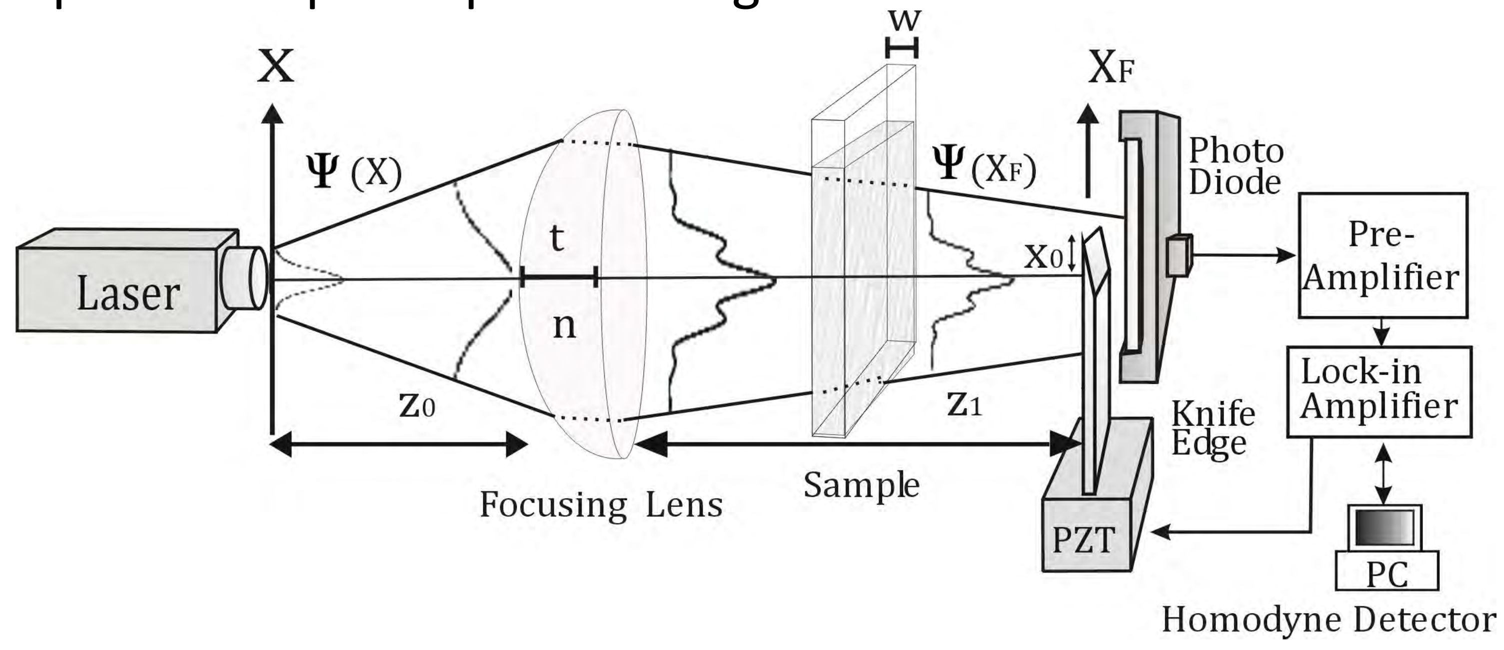

Fig. 1. The vertex of a singlet focusing lens with central thick t is placed at a distance z_0 from the waist-plane with coordinate x of a laser Gaussian beam with amplitude distribution $\Psi(x)$. The observation plane with coordinate x_F is located at a distance z_1 from the back surface of the lens. A transparent sample with width w is placed between the lens and the observation plane. The intensity of the final distribution $\Psi(x_F)$ is acquired by a Homodyne detector. (We have reported a similar figure in [3]).

3. Results of measurements

In figures 2(a-d) it is depicted how at a near vicinity of the back focal plane of a focusing singlet, spherical aberrations of an illuminating commercially available He-Ne laser beam with a Gaussian intensity profile are attained as the distance between the laser and the focusing singlet (z_0) increases.

In a previous report [3] we have demonstrated that the Gaussian probe beam free of aberrations is less sensitive to glucose concentration changes as compared with the Gaussian probe beam with high spherical aberrations.

It can be appreciated from Fig. 3(a-c) how the primary side-lobes heights increase while the index of refraction of the sample under inspection increases. The system is adjusted by setting the height of the primary side-lobes to a vertical height of 60% when the sample under inspection is filled with tri-distilled water which corresponds to a concentration of C_A=0 mg/dl for a fixed distance z_1. Once the system has been adjusted we proceed in measuring liquid samples with different known glucose concentrations to calibrate the system. Once the system has been calibrated, it can be used in a simple way, since it shows a linear response, even if there is a small misalignment, Fig. 4.

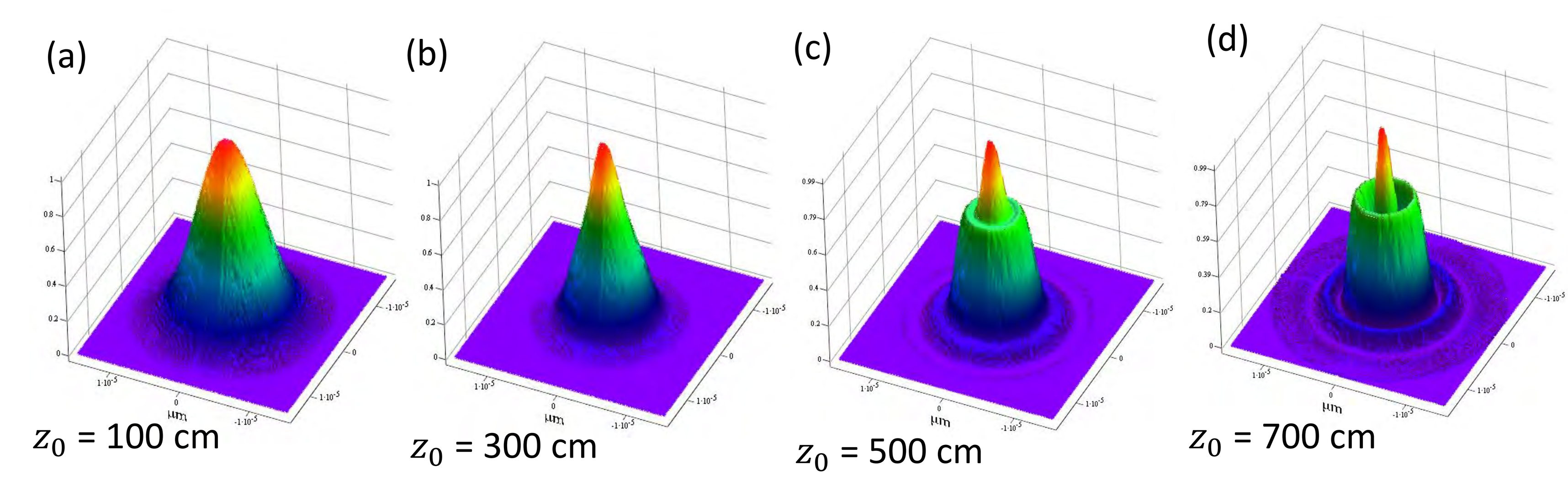

Fig. 2. (a- d) Development of spherical aberrations at a vicinity of the back focal plane of a focusing singlet, illuminated by a commercially available laser beam with a Gaussian intensity profile as the distance (z_0) increases.

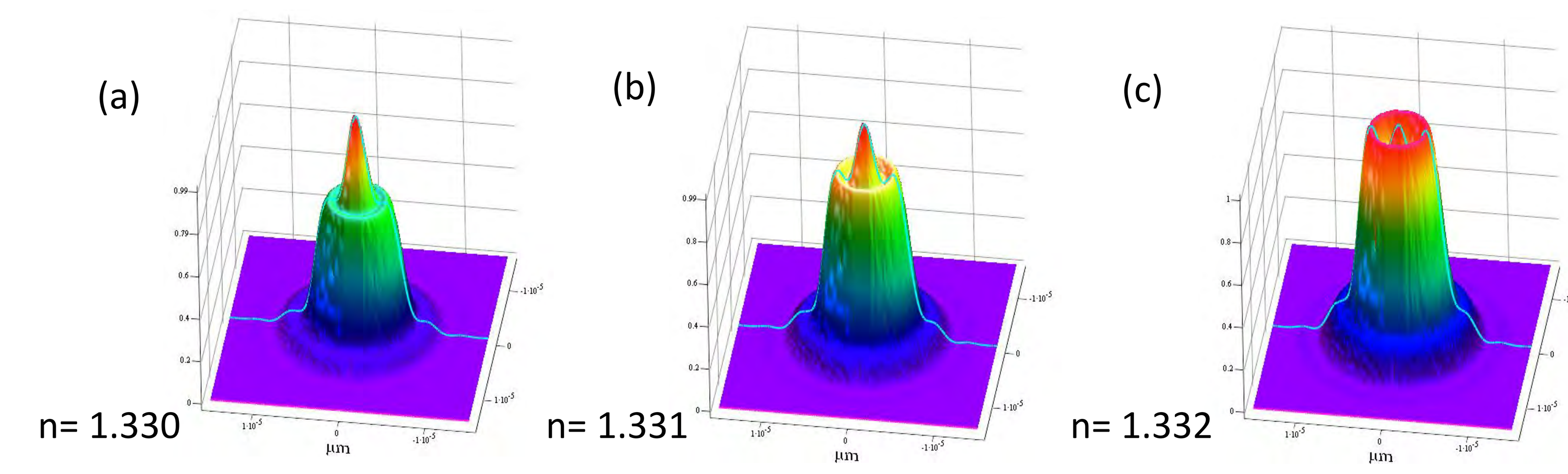

Fig. 3. (a-c) Increasing of the heights of the primary side-lobes of the detected probe beam as the glucose concentration increases in the sample under inspection. z_0=500 cm , Δn= 0.001which corresponds to approximately changes of 500 mg/dl between samples (the concentration changes are exaggerated for visualization purposes).

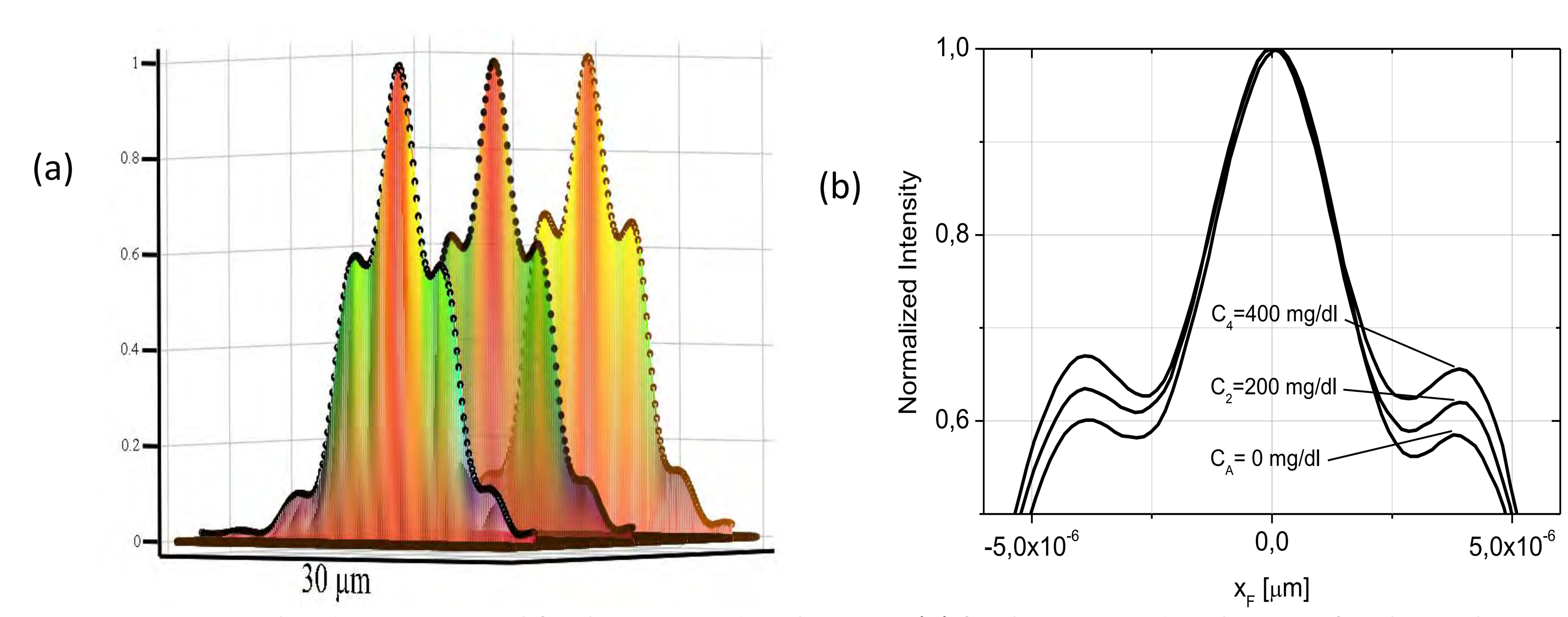

Fig. 4. Normalized experimental final intensity distributions. (a) final intensity distributions for three glucose concentrations C_A=0 mg/dl,C_2 =200 mg/dl, and C_4=400 mg/dl. (e) corresponds to a zoom.

4. Conclusions

We demonstrated analytical and experimentally that a Gaussian probe beam with high spherical aberration is more sensitive than a Gaussian probe beam free of aberrations for glucose concentration measurements. We demonstrated experimentally that the system has a linear response in a range of interest with high repeatability and stability, making this system feasible for glucose concentration measurements in transparent liquid media. As the system exhibits a linear response an additional advantage is that the system is still reliable even over slightly misalignments.

5. References

[1] McNichols, R. J., & Coté, G. L. (2000). Optical glucose sensing in biological fluids: an overview. Journal of biomedical optics, 5(1), 5-16.

[2] So, C. F., Choi, K. S., Wong, T. K., & Chung, J. W. (2012). Recent advances in noninvasive glucose monitoring. Medical Devices (Auckland, NZ), 5, 45.

[3] Yáñez, E., Cywiak, M., & Franco, S. J. M. (2018). Gaussian probe beam with high spherical aberration for glucose concentration measurement. Applied optics, 57(15), 4153-4157.