SUPER CONTINUUM LIGHT SOURCES FOR SCATTERING AND ABSORPTION SPECTROSCOPY – A TIME STUDY OF FOAM DEFLATION

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4. Arla A/S. 5. DuPont 6- Videometer A/S

Application

Milk Fermentation – During acidification of milk, a protein network is formed by interlinked protein chains. This is changing the rheological properties (more firm) and can be monitored using light scattering.

Raw material **Fermentation** **Product**

Whipped cream **Measurement procedure**

Abstract

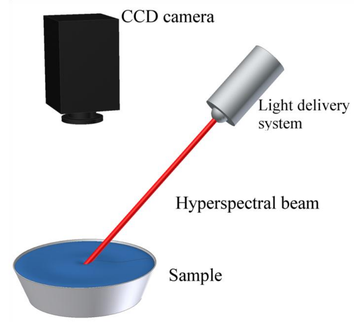
During production of colloidal products, it is often desirable to monitor the microstructure to ensure a uniform high quality. On this poster we demonstrate how the scattering of light can be used to monitor changes in micro structure.

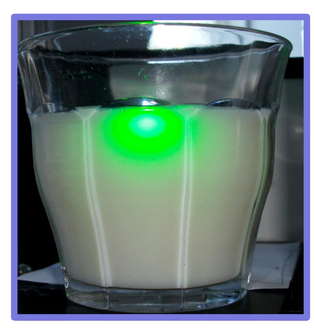
This is particular the case during foam formation in a whipping process where no chemical changes occur. This technique can further be applied in a wide range of structure forming process and here substitute traditional rheology measurements. Examples include cheese gelation [I], fermentation process in milk, but also the stability of emulsions [II].

The instrument is previously presented in [III,IV] and analyse static scattering from the sample. Here we combine it with a novel technique presented in [V] to quantify the sample's scattering and thereby structural property.

Inspection system

Experimental setup for measuring diffuse reflectance. The oblique –incidence illumination with the collimated super continuum beam.

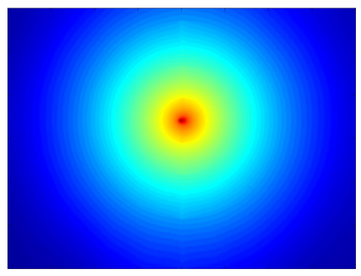




diffuse reflectance in milk

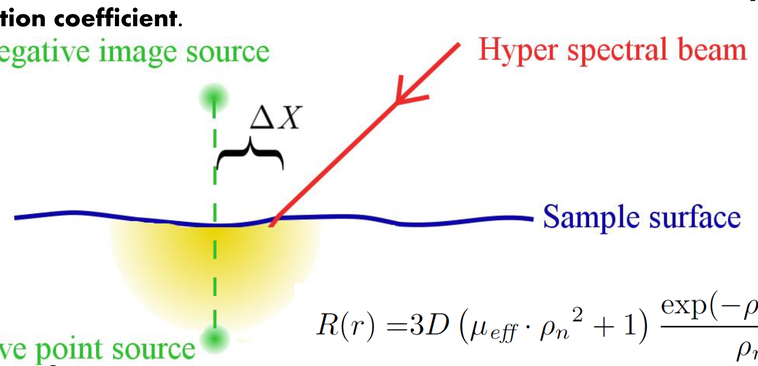
Image example , false color and log scale. We use a single line through the profile.

J. Skytte will present result on analysing micro of the full image on Wednesday.!



Model for oblique-incidence

The diffuse reflectance is analyzed using the technique of oblique-incidence as presented by Wang et al. and illustrated below. This technique eliminates the need for measuring absolute values of reflected intensity. The scattering is approximately determined by measuring the difference between the incident point and the center of the diffuse reflectance. Afterwards an analytical expression is fitted to obtain the absorption coefficient.



$$\mu_a = D\mu_{eff}^2$$

$$\mu_s' = \frac{1}{3D} - 0.35\mu_a$$

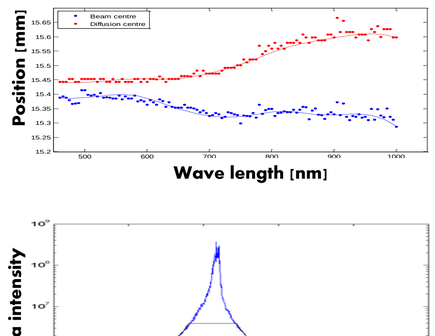
$$R(r) = 3D\left(\mu_{eff}\cdot {\rho_n}^2 + 1\right)\frac{\exp(-\rho_n\cdot\mu_{eff})}{{\rho_n}^3} + (3D + 4AD)\left(\mu_{eff}\cdot {\rho_p}^2 + 1\right)\frac{\exp(-\rho_p\cdot\mu_{eff})}{{\rho_n}^3}$$

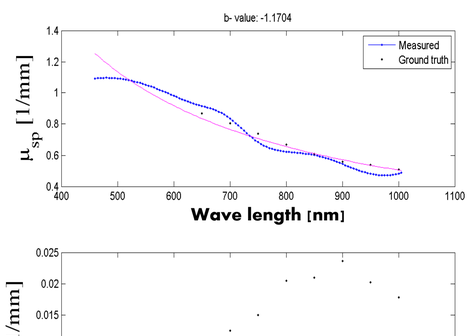
The optical parameters is connected to the micro structure through Lorenz-Mie theory

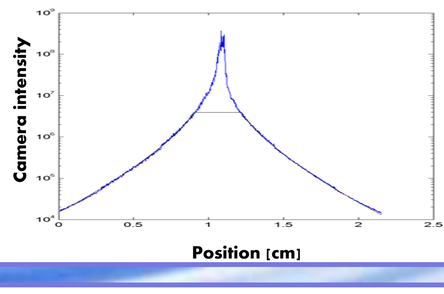
1) **Particle size**
2) **Particle density**
3) **Particle shape**

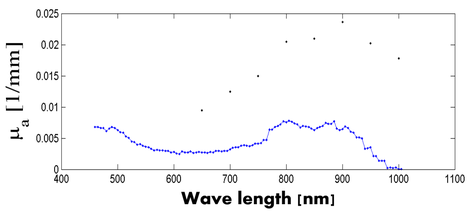
Validation on optical phantoms

The first measurements have been performed on a optical phantom to estimate the system performance accuracy. The measured displacements of the beam and diffusion center is presented below as a function of wavelength. An example of the fitting results is presented in II. The resulting estimates of scattering and absorption is presented in III.



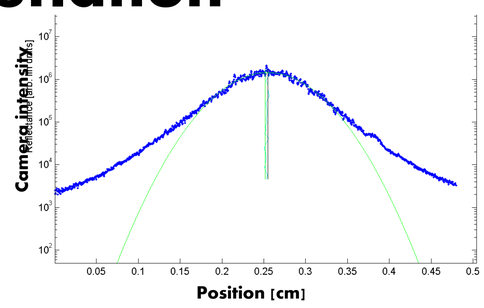


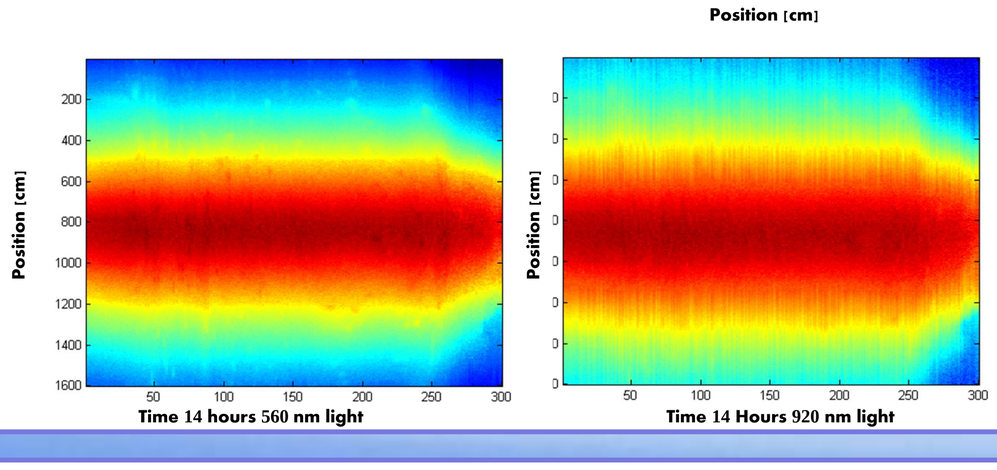




Foam deflation

During deflation the double size distribution will change due mainly because of collapses. The upper left corner of the poster show an image of the measurement sequence. A glass container was filled with foam and sealed. The optical properties was measured at the top of the foam.

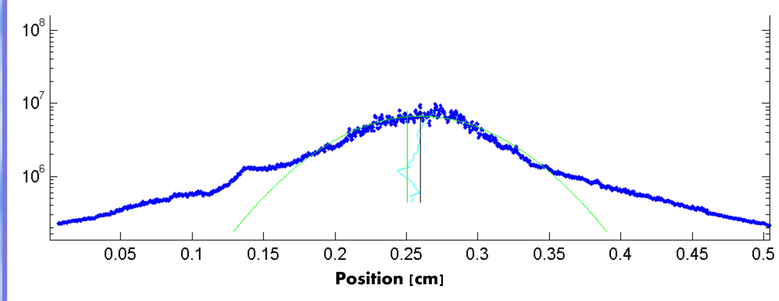


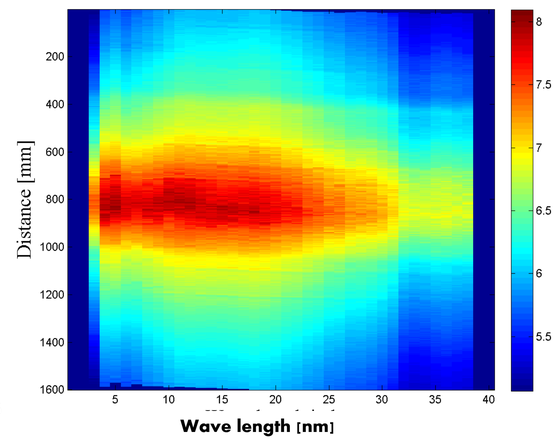


Pure milk samples

The first measurements have been perform on Milk samples, the graph below show results on measuring the mea free path on pure milk (3.5 % fat)

The intense scattering impose a requirement for high pixel resolution (~3 um / pixel) and a tightly focus beam.

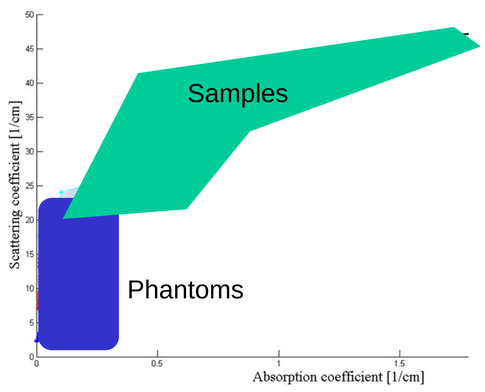




Conclusion

We have introduced a new technology for inspection of fluids described as the oblique incidence reflectrometry. The method have been used to characterize phantoms with know optical properties. Lastly we have started to transfer the knowledge on the phantoms to foam and milk products as presented above.

It's our belief that this pursue of physical interpretable parameters may prove a beneficial step towards inspection of fluids in production.



Outlook

Short term projects:

More accurate determination of absorption coefficients

- Compare with ground truth measurements
- Correct for possible chromatic lens distortion
- Examine effects of the beam profile

Long term projects:

Online process characterization of milk fermentation

- Comparison with rheology, sensoric test panel etc.

Adding wavelengths in the NIR regime, **1100 – 2400** nm

- More chemical specific response

References:

[I] M.J. Mateo, D.J. O'Callaghan, C.D. Everard, C.C. Fagan, M. Castillo, F.A. Payne, and C.P. O'Donnell. Food Research International (2010)

[II] Jérôme Dillet, Christophe Baravian, François Caton, and Alan Parker, Applied Optics Vol 45. No. 19 (2006)

[III] O. H. A. Nielsen, A. L. Dahl, R. Larsen, F. Møller, F. D. Nielsen, C. L. Thomsen, H. Aanæs, and J. M. Carstensen. Scandinavian Conference on Image Analysis – Proceedings, Lecture Notes in Computer Science; 6688, page 327.337, Springer, (2011)

[IV] O. H. A. Nielsen, A. L. Dahl, R. Larsen, F. Møller, F. D. Nielsen, C. L. Thomsen, H. Aanæs, and J. M. Carstensen. Scandinavian Workshop on Imaging Food Quality (SWIFQ), 2011, Ystad, Sweden

[V] Shao-Pow Lin, Lihong Wang, Steven L. Jacques, and Frank K. Tittel. Measurement of tissue optical properties by the use of oblique-incidence optical ber reectometry. Appl. Opt., 36 (1):136{143, Jan 1997. doi: 10.1364/AO.36.000136.