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Ocean Science Discussions

Interactive comment on "Optical tools for ocean monitoring and research" *by* C. Moore et al.

Anonymous Referee #1

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Here is an excellent paper easily readable by non-specialists. The authors have put emphasis on two particular points. The first one has been to demystify an old idea which was that optics, for many reasons, will never be appropriate for oceanographic measurements. With numerous references they demonstrate that from the basics IOPs and AOPs underwater measurements, application of optics has moved towards more sophisticated techniques offering new solutions and perspectives to the oceanographers community. The second point has been to bring a maximum of informations to relate each presented techniques to the different applications. This provides to the reader an acurate overview of what can be done to increase the efficiency in water quality assessment not only in physics but also for in situ chemistry and biology. They also emphasize the fact that marine technology has taken a major benefit from the new components developped during the last decades. The new miniaturized light sources such as solid state Laser and LED, available over a broad wavelength range with easier mode of operation and lower power consumption have brought to engineers and instrumental designers lot of interesting implementation possibilities for deep sea or long term monitoring applications. In the same order, the technical improvements of new detectors array have been particularly suitable to develop instrumental set-up conveniently to improve applications of the complex theory of optical scattering. The standardization of the technology has been also a great advantage with commercially available data managment software, offering to the researcher, lot of opportunities to get real time measurements from a profiler or any underwater platform connected to a surface ship or a long range satellite communication systems. In the paragraph “looking forward”, the authors have also sensibilised the reader to the futur. It appears clearly that optics will also stimulate other technological fields such as MEMS, in conjunction to specific surface functionnalisation process which will open the way to Lab-on-chip concept to ocean research and seawater monitoring.

Specific comments 1) Introduction: Being sure that the authors have made the maximum to be exhaustive in the ennumeration and description of the optical techniques applied to ocean monitoring, it is sometimes diffcult to find the boundary between the two contexts of applications given by the free space marine optics and optics used as a transducing techniques. Free space optics generally concerns short pathlength and small sample volume of water and it is sometimes a problem with regards to the immensity of the underwater environment. It is a reason why it seems to me that it is not relevant to exclude Imagery and Lidar from the following descriptions. The techniques are both applied to study small physical structures over a wider space than a sensor. Imagery gives basically to the underwater observer a 2D vision of the water components. We must not forget that Imagery is still a basic optical tool in oceanography. The CCD technology has openned the way of numerical imaging systems essential to science and particularly in marine science for research and monitoring as well. If it has been used for a long time as a simple eye to navigate or to identify geological, geophysical structure or living macro-organisms, it has progressively moved towards observations of free flowing particulate matter. Among the most significant applica-

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tions, video and highly resoluted imagery coupled to laser beam configuration, are now commonly used to observe free living species down to the micro-scale (Gorki). The spectral dimension is also taken into account and when using an appropriate laser wavelength, fluorescence measuements are also possible to discriminate phytoplancton (Jaffé). Bioluminescence detection can also be monitored thanks to time integration capability as it has been done around deep hydrothermal vents (Van Dover, White). To show how much optics and imagery has no limits in terms of in situ instrumentation developments, still unthinkable several years ago, underwater holography has become a reality in numerous applications (J. Watson Aberdeen University.: Katz, Osborn at John Hopkins Uni). At least concerning imagery, I agree that it is wide topic but it seems to me important to show that it is more and more a measuring tool than a simple vison technique.

The Lidar approach have been motivated by similar reasons than for imagery. Lidar technique offers a possibility to stimulate the water column over a longer distance than it is possible with classical optical sensors. In my opinion a paper which aims at providing an overview of marine optics cannot omit to describe Lidar techniques as it has been a frame for important work all over the world (see Reuter et al; Stute ; Chekalyuk; Boniforti) The laser technology is continuously evoluting and solid state components emitting at high rate, short green pulses (532nm), gives lot of opportunities to develop underwater non intrusive optical tools. The production of fibre lasers which are able to deliver similar power than conventionnal Nd-YAG with higher efficiency ratio will potentially put in the next future this technique to the top of underwater optical tools for oceanography. Lidar is a relevant technique to be operated on underwater vehicles (Towed or ROV) or hull mounted on a ship giving a 3D description of few meters of water. Lidar is an underwater instrumental set-up which can be settled on immersed carriers, not only on aircraft.

“Plateforms and applications” is obviously important, as they always play a role in the measurement startegy. Plateforms are not simple carriers. They are

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essential to locate the water sample to be measured either on a mooring system or on moving frame such as undulating (or not) towed vehicles. This paragraph would have been common to all the techniques described in the paper.

Comments on SERS technique There is an ambiguity to describe SERS as a Raman technique similar to what is done by DORISS which is closer to Lidar. SERS is typically what I called transducing techniques. SERS is devoted to increase the sensitivity and selectivity in the detection of chemicals weakly soluble in water. The surface enhancement is the key problem more than Raman measurement and it is more or less similar to SPR technique which follows the same phylosophy.

SPR Technique. SPR is well described and interesting perspectives are presented. It is typically a transducing techniques very promissing for in situ biomolecular measurements absolutely pertinent to monitor armful microspecies blooms. SPR technique is also suitable to be applied to optical fibre sensors.

Optodes The definition of an optode must be clarified. Is basically an optical transducer which can be operated freely in the ocean? The word optode is often used for optical fibre technology. In that topic, O2 optode is one of the most significant development which is now commercially available. Optical fibre sensors are also included in the field of optodes. It seems to me important to mention the case of salinity sensors which have been the frame of several interesting works. Refractometry is basically the principle which link dierctly the refractive index to salinity and density. SPR which has been presented page 682, has been applied on a monomode fibre (see N. Diaz-Herra). A dielectric layer has been deposited on a side-polished fibre, the transmitted light is continuously modulated by the evanescence from the dielectric layer in contact to sea water. In the same order K Marht used the total refraction from a prism and built an optode to measure salinity on free falling profilers. V. Vlasov in Russia have also built a probe which used a Mc Zender interferrometer with several arms capable via inversion process to deliver refractive index, salinity temperature and pressure on the same sample.

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Looking forwards. There is an important topic which is missing in the paper: the use of optical fibres in marine instrumentation. Fibre optic is not an optical technique in itself, as light is travelling along an optical channel and never propagates entirely in the water. Nonetheless, it is important to remind the reader about the improvement brought by Optical fibre in data transmission particularly for ROV operations. It is also the basis in the concept of underwater seafloor observatory networks (see EU; ESONET, neutrinos telescope ANTARES). Optical fibre is also suitable to make distributed measurement. By generating localised modifications of the fibre core structure like Bragg gratings or simply through Brillouin scaterring analysis, any stress provided along the fibre can be measured and localised according to OTDR techniques over distances of several kilometers long. This technique will be well-suited to monitor large area exposed to geohazard events.

Page 669 line12 invert “is” and “it”

Conclusion

It is always difficult to make a full state of the art in underwater optical applications as this field is supporting constant inovative works. The present paper is certainly the first which gives the most realistic image of what is actually done. It contributes to widely promote optics as one of the most suitable way to understand and monitor the Oceans. Even if some topics would have been more detailed, I think that this paper can be published .

Interactive comment on Ocean Sci. Discuss., 5, 659, 2008.

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