using micro-machining. MEMS have shown encouraging results for sensing physical parameters, but work is needed to realize their full potential for chemical sensing. Most work with MEMS has been done in laboratories thus far; however, transitioning to *in situ* applications seems feasible. Potential advantages of MEMS and nanotechnologies include: auto-calibration, self-testing, digital compensation, small size, and economical production.

2.6.2 Bio-optical Sensors and Systems Bio-optics have gained increasing attention in part because of new technologies and growing realization of their central importance to several ocean problems involving biological-chemical-optical-physical interactions including primary productivity, upper ocean ecology, biogeochemical cycling and the biological pump, and bio-optically modulated variability in upper ocean heating rates (see Figure 2 and reviews by Dickey, 2001a,b, 2002a, Chang and Dickey, 2001, and Dickey and Falkowski, 2002). Optical properties are typically biologically modulated in the open ocean whereas terrigenous input and resuspended sediment also play major roles in the coastal oceans.

Two operational classifications of bulk optical properties are most useful for the following discussion: inherent optical properties (IOPs) and apparent optical properties (AOPs). IOPs depend only on the ocean water medium (pure seawater and its various constituents) and are independent of the ambient light field. On the other hand, AOPs are those properties depending on both the IOPs and the geometric structure of the subsurface light field. Instruments designed for underwater light observations are usually described as measuring either IOPs (e.g., spectral beam attenuation, absorption, and scattering coefficients) or AOPs (e.g., spectral diffuse light attenuation coefficients). Recently developed instruments are capable of measuring light absorption, scattering, and attenuation at multiple wavelengths (from 9 to about 100 different wavelengths). Likewise measurements of diffuse light attenuation have increased spectral resolution to a few nanometers in the visible. The power of these types of instruments lies in their ability to distinguish phytoplankton from detritus and dissolved materials, and potentially to identify phytoplankton (perhaps including harmful algae) at least by community groups. See Dickey (2001a) for more details.

Estimation of primary productivity is an important goal as mentioned earlier and several different optical measurements have been used (e.g., Dickey and Falkowski, 2002). Again, examples include the use of chlorophyll fluorescence and photosynthetically available radiation (PAR) measurements in empirical models and more sophisticated measurements using "pump and probe" fluorometers (Kolber et al., 1998). The latter instruments have the important advantage of providing information about