is calibrated against optically pure water, and the derived absorption and beam attenuation coefficients are $a(z,\lambda)-a_{\mathrm{w}}(z,\lambda)$ and $c(z,\lambda)-c_{\mathrm{w}}(z,\lambda)$, respectively (Volume IV, Chapters 2 and 3).

- **HYDROSCAT-N** (**HS-N**): A "backscattering meter" manufactured by HOBILABS, that measures a weighted integral of the volume scattering function (VSF) $\bar{\beta}(\bar{\lambda},\bar{\Psi};c)$ at a central scattering angle of $\bar{\Psi}=140°$, at N wavelengths. The backscattering coefficient $b_{\mathrm{b}}(z,\lambda)$,is then determined using a model relating it to $\bar{\beta}(\bar{\lambda},140°;c)$ (Volume IV, Chapter 5). Alternatively, one of the N channels may be configured to measure chlorophyll a fluorescence, rather than backscattering. On the MOOS buoy, for example, a hull-mounted HS-2 is used to determine $b_{\mathrm{b}}(z,532)$ and chlorophyll a fluorescence at a depth of approximately 1.5 m.
- **VSF**: A device similar to the HS-N, but which measures $\bar{\beta}(\bar{\lambda},\bar{\Psi};c)$ at 3 centroid angles, $\bar{\Psi}=100°,\ 120°$ and $150°$, at a single wavelength, and determines $b_{\mathrm{b}}(z,\lambda)$ using a model of the VSF that is different from that used with the HS-N (Volume IV, Chapter 5).

Protocols describing methods for measuring these variables, including laboratory and field calibrations of instruments and quality control measures, are described in Volume IV, Chapters 2, 3 and 5 for $c(z,\lambda)$, $a(z,\lambda)$ and $b_{\mathrm{b}}(z,\lambda)$, respectively. As with radiometry, the measurement protocols for IOP instruments on buoys differ from shipboard protocols in that they are usually placed at fixed depths, they are subject to biofouling during lengthy deployments, and the instrument cleaning and field calibrations recommended for shipboard use can only be carried out before and after the deployment. Profiling moorings may mitigate bio-fouling problems by "storing" the instrument package in the dark at a depth below the euphotic zone.

Manov *et al*. (2003) review methods for reducing biofouling of IOP, as well as AOP, sensors. In particular, they (OPL UCSB) have developed An anti-foulant copper tubing flow-through system was developed by USCB OPL for the ac-9 and HiSTAR (100-wavelength ac-meter) (Figure 3.14), for closed path flow-through fluorometers (WET Labs, Inc. WETStar) and transmissometers (WET Labs, Inc. C-Stars). The copper tubing systems were tested on a mooring, at depths of 5, 11, and 20 m, during the Hyperspectral Coastal Ocean Dynamics Experiment (HyCODE) in productive inland waters off New Jersey, U.S.A (Chang *et al*., 2002). One-half inch copper tubing was utilized to connect the intakes of the ac-9 to a pump. Between one-hour measurement cycles, copper from the tubing was allowed to leach into the water contained in the tubes of the instrumentation system. Prior to taking the absorption and attenuation measurements, the pump was run on for 10 seconds to clear the system of the leached copper and to pump non-contaminated water into the intake port for sampling. The pump was then left on during the 70 s measurement period. Stainless steel screen filters were used to remove large particles, *e.g.*, seaweed, macroorganisms, and large detritus, from the sensor elements. Separate pumped water systems were utilized for the plumbing the WETStars and C-Stars. One-quarter inch copper tubing was utilized to fit the two instruments together and to a pump. Isolation of the copper by Tygon tubing (black tubing is used to reduce ambient light levels) was made in order to avoid dissimilar metal corrosion effects with the sensors pressure cases, mounting brackets, and the stainless steel instrumentation cage. Manov *et al*. (2003) concluded that copper-tubing based systems provide biofouling protection superior to that achieved with chemically-based methods.

It is recommended to deploy one set of IOP sensors in the near-surface layer at a depth centered between those at which radiometers are placed to determine $K(\lambda)$ and $L_{\mathrm{WN}}(\lambda)$ (see above). If additional IOP sensors are deployed in an array, the usual practice is to distribute them to optically characterize the water column throughout the euphotic zone.

These guidelines are appropriate, though perhaps difficult to adhere to in practice. The GoMOOS moorings, for example, deploy one set of IOP sensors at 3.5 m depth. This IOP package includes:

- Three WETLabs VSF (440, 530, and 650 nm) volume scattering meters are integrated with a VSF3S controller that controls the sampling period for each of the 3 sensors, and collates the data from all 3 sensors into a single output stream to the buoy's DH4 data logger, where sample period averages are formed. Each VSF sensor has a small copper shutter that covers the optical sensing area when not in operation, and rotates out of the way during the measurement period. The copper shutter sits about 1-2 mm above the optical face. Copper foil tape is also wrapped around the outside of the sensor to deter growth.