In situ digital holography for harmful algal bloom monitoring and research applications

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Harmful algal blooms (HABs) are increasingly impacting aquatic systems across the globe. Early detection and monitoring plays an important role in mitigating harmful impacts as well as understanding HAB ecology; thus, it is imperative to push the envelope towards adoption of new methodologies for rapid and accurate characterization of HAB-forming species. Traditional methods usually involve collecting water samples using bottles or nets, which tend to break up particle aggregates, thus inducing a bias in measured particle size distributions. In situ imaging approaches to analyze field samples for plankton community composition, including HAB-forming species, are thus attractive propositions, especially when coupled with machine learning tools for rapid detection and identification of target groups. Digital holography is one such imaging technique, which is capable of resolving undisturbed 3-D particle fields in their natural environment.

This talk will begin with a brief discussion on the holographic method, demonstrating its usefulness for in situ applications. We will then describe the development of a new generation holographic imaging system (AUTOHOLO) custom-built at Florida Atlantic University. The AUTOHOLO uses a pulsed, 532 nm laser as the illumination source and a high resolution (4920 x 3280 pixels, 16 MP) camera as the recording medium. The modular optical configuration allows for a resolvable particle size range from a few microns to ~ 2.5 centimeters. Sampling volumes up to 71.4 mL/hologram can be achieved, which is an order of magnitude higher than that possible with currently available commercial holographic imagers. The camera records holograms at maximum sampling frequencies up to 3.2 Hz, corresponding to ~ 15 L of water sampled every minute. A short overview of the holographic data processing techniques will then be provided, followed by sample applications demonstrating the AUTOHOLO's feasibility for utilization in HAB studies across freshwater and marine environments. In particular, we will discuss two separate projects: (a) field efforts of the AUTOHOLO in the Gulf of Mexico for detection of the red tide causing organism, *Karenia brevis*; and (b) multiple deployments in Lake Erie to characterize cyanobacterial bloom dynamics, with a focus on *Microcystis*. Additionally, we will also highlight results from a previous generation holographic imaging system in Lake Erie to show how these high resolution observations allow for better understanding of cyanobacterial ecology. We will wrap up the discussion by talking about potential bottlenecks as well as future advancements necessary for expanding the scope of digital holographic systems and their potential integration into long-term plankton/HAB monitoring networks.