UTOFIA
Underwater Time Of Flight Image Acquisition

Newsletter #3
October 2016

A "Little-BigMOPA" for UTOFIA

Bright Solutions report on a new laser development.

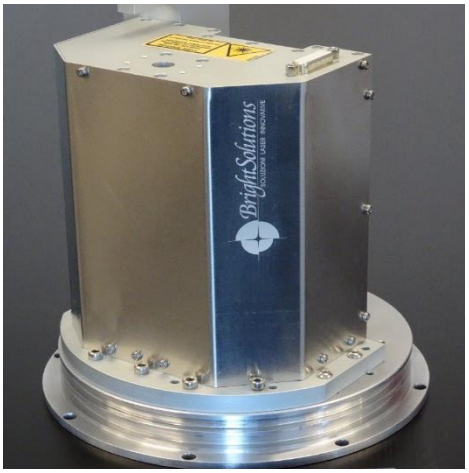

Figure 1: *Little-Big MOPA: a reliable, rugged and compact solution from UTOFIA*

UTOFIA aims to build of a compact and cost-effective underwater imaging system for turbid environments focusing on its reliability, ruggedness, and compactness. Using range-gated imaging technology assembled in a preliminary version with off-the-shelf commercial components supplied by the partners, the system has already demonstrated to be able to extend the imaging range by factor 2 to 3 over conventional video systems, while at the same time providing in the meanwhile 3D information extracted by image data processing.

After the first successful proof-of-concept demonstrations, we turn our attention to advancing the project to a higher level of competitiveness. New challenges to be faced include:

- Higher pulse energy needed for bettering distance and angular ranges;
- Improved management and control of laser cooling and power budget;
- More compact laser packaging to reduce marine housing dimensions and volume, and increase overall ruggedness.

All of these issues require a next step in UTOFIA system design, in particular for the laser, where reliability, ruggedness, and compactness are the major and most challenging requirements. As "a picture is worth a thousand words", the essentials of the solution found by Bright Solutions can be seen here.

Here the laser package is shown mounted on the back flange of the marine housing containing the the UTOFIA system. A radical reduction in size to less than 2 liters, and robustness of the laser were accomplished together with the enhancing of all its other specifications. This result justifies the nickname "Little-BigMOPA" we have given to the new laser.

In addition to the laser components, frequency doubling and beam shaping optics, the package houses all the electronic and control components that assure the reliable operation of the pulsed green laser. MOPA itself is an acronym meaning Master

Oscillator-Power Amplifier, indicating the laser design chosen in order to get the pulse energy/pulse duration/repetition rate/beam quality/stability specifications of the upgraded laser system. A summary of the laser technical specifications is given for the interested reader in the table at the end of this page (cf. Figure 3).

A charming first test of the laser illuminator's uniformity was conducted thanks to the courtesy of a fish occasionally passing by our laboratory at Bright Solutions. The picture was taken using a diverging lens. Illumination uniformity in water can only improve once the beam diffusing optics of the marine housing are installed.

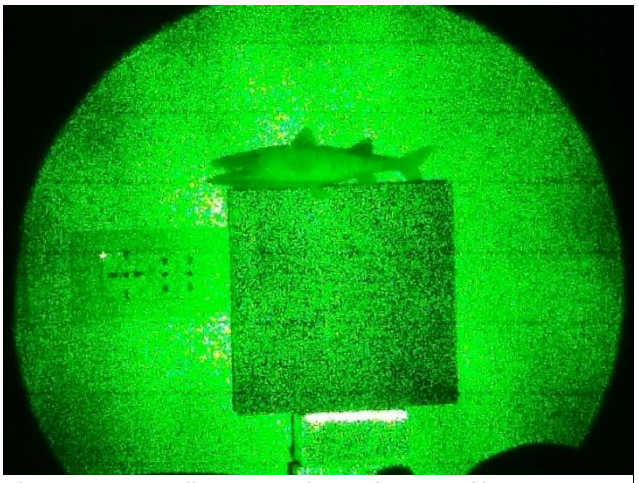

Figure 2: *Image illustrating the uniformity of laser's illumination*

It has not escaped our notice that the specific design, reliability, ruggedness, and compactness of this new laser immediately suggests its possible use in many other outdoor application (for instance, LIDAR, navigation in foggy conditions) where the harsh environment makes it difficult to operate with more conventional laser sources.

Parameter	***Value***	***Notes***
Wavelength	532.2 nm	*In air*
Q-switch rep-rate	Single-shot to 1 kHz	*Active*
Pulsewidth	< 2 ns	*See picture*
Pulse energy	> 2 mJ	*@ 1kHz repetition rate*
Polarization	Linear >100:1	
Beam Quality Factor, M^2	<3	*See picture*
Output beam diameter	≈ 2 mm	
Cooling	Conduction	*Through baseplate*
Laser Volume	<1750 cm^3	*< 2l*

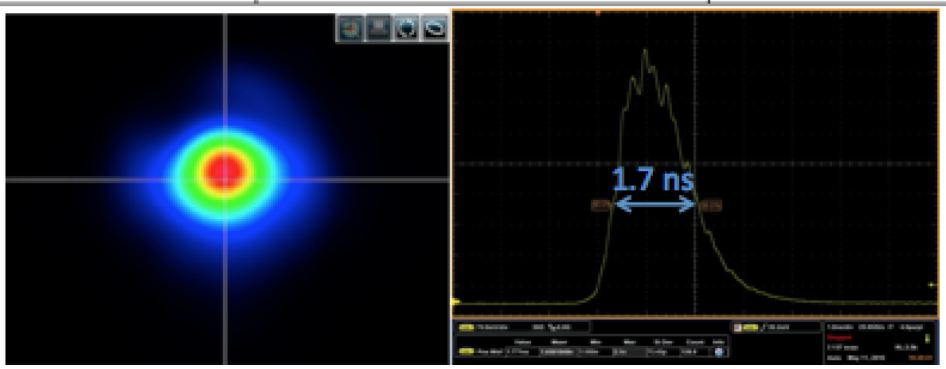

Figure 3: *Technical specifications*

UTOFIA'S first student graduated from DTU

Jane Behrens of DTU Aqua

Figure 1: *Simon Jarnit*

This summer UTOFIA´s first graduate student Simon Jarnit (Figure 1) defended his Master's degree from the Technical University of Denmark, under the supervision of Dr. Jane Behrens. Simon presented in his thesis the results from the first UTOFIA trial testing the potential effects of the laser on cod physiology and behavior (see previous newsletter). In brief, cod were surgically implanted with heart rate loggers (heart rate is a good measure of stress in fish) and allowed to swim freely in a big tank where the laser was turned on for 10 min daily during five days. The setup of the tank is shown in Figure 2.

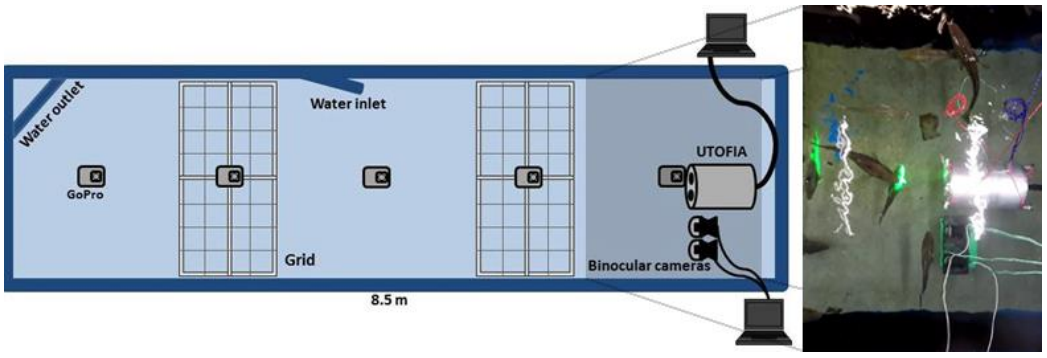

Figure 2: *Schematic of the experimental setup for monitoring physiological and behavioral response of cod to the UTOFIA system (not to scale). Shown are tank dimensions, underwater placement of the UTOFIA system, the binocular cameras and the grids, in addittion to the placement of GoPro cameras above the tank. The UTOFIA system and binocular cameras were each connected to a PC equipped with a customized software programmes. The insert (photo) shows the cod swimming in front of the laser (green light).*
Follow this link to a film clip of the experiment.

Besides measurements of heart rate (Figure 3), behavioural responses to the laser were also investigated, combining high-resolution video with a fish tracking algorithm to detect swimming behaviour and fish spatial distribution within the experimental tank. And it appeared that the cod did not care at all about UTOFIA laser (Figure 4).

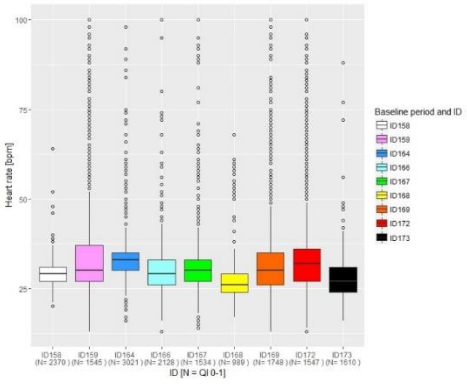

Figure 3: *Basal heart rate of individual fish. Solid line is the median, box is the interquartile area (bottom and top are 25th and 75th percentiles, respectively). Whiskers show either the max/min observation if within 1.5 of the interquartile range or 1.5 times the interquartile range. Circles are observations (outliers) not covered in the area between the whiskers respectively. N is the number of measurements*

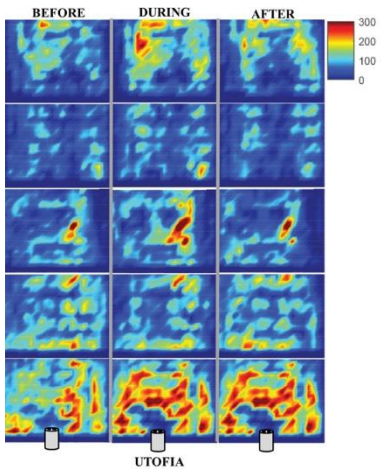

Figure 4: *An example of an activity map (day 4 of the experimental period) showing fish activity before, during and after the UTOFIA laser was turned on. Each frame corresponds to a GoPro camera placed above the tank. The UTOFIA system is illustrated at the bottom of the figure. The scale ranges from 0-300*

The heart rate – being on average 31 beats per minute and varying between 28 and 35 beats per minutes for the nine experimental cod (figure 3) – was unaffected by the laser source, and, likewise, swimming speed and distribution within the experimental tank remained unchanged irrespectively of the laser being turned on or not

While this study resulted in the very gratifying conclusion for the UTOFIA project - showing that the laser did not appear to have any physical or behavioural effect on cod, a precautionary approach is always needed when applying the UTOFIA system under field conditions to mitigate any potentially adverse effects on the organisms inhabiting these systems.

The Annual Meeting 2016

During 7-8 of June, representatives from each UTOFIA partner descended on Edinburgh to attend the first annual general meeting of the project consortium. Convening directly in the shadow (Figure 1) of the famous castle, the meeting was held in the rooms of the Royal Overseas League, a not-for-profit members' club dedicated to championing international friendship and understanding, and an entirely appropriate venue for an European wide H2020 project.

Many of the team members arrived a day earlier than the formal assembly, in part to enjoy more of the Scottish weather and hospitality, as well as to participate in dedicated project workshops at the offices of Odos Imaging. Many topics were addressed during the day, including low-level algorithm design, the planning and scheduling of real-world tests of the UTOFIA cameras, as well as discussing the specifications and end user requirements of the UTOFIA cameras. The workshops also provided a welcome opportunity to discuss project details face-to-face between team members.

Edinburgh Castle as seen from the meeting rooms of the Royal Overseas Lodge

A packed agenda at the formal assembly focused on the progress made by the partners within each work package. Instantaneous and uncompromising peer review at the conclusion of each presentation added a lively and sometimes spirited element to the proceedings, but was unanimously agreed to have been an enjoyable process overall. A highlight of the day was the first consortium wide demonstration of the UTOFIA 'System One' camera, expertly assembled by the SINTEF engineers on the previous evening in the corner of the meeting room. Several team members took the opportunity to be models for the day, and have their images captured in reconstructed 3D from the range-gated operation of the camera.

The UTOFIA team

The end of a long day saw the consortium gather at the small 'Gardener's Cottage' in the historical Royal Terrace Gardens, to enjoy a meal of local and seasonal produce, as well as a small dram of Scotland's most popular export.

The assembly continued in the morning with the much anticipated review of reporting for the period together with formal votes on consortium matters, including the unanimous agreement to assemble in Bilbao, June 2017, for the second annual general assembly. The meeting concluded with a round table discussion of potential opportunities for exploitation and dissemination of the results of the project, leaving the team on an upbeat note as they departed for the airport.