EAGER: MEMS Co-Steered Optical and Acoustic Dual Modal Communication and Ranging Devices for Underwater Vehicles

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Project Overview

The objective of this exploratory project is to develop a new transformative dual-modal sonar and LiDAR combo device based on novel water-immersible microelectromechanical systems (MEMS) scanning mirrors (WIMSMs) and ultrasound transducers to enable both underwater communication and perception simultaneously. We name this device as oPtical and Acoustic communication and Ranging (PAIR) device. The PAIR device can provide fast steering and simultaneous transmission/reception of co-centered and co-directional ultrasound and optical beams with a single compact MEMS scanner, which significantly reduce device size (Fig. 1).

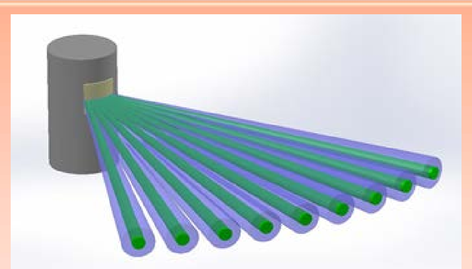

Fig. 1 An illustration of how a PAIR device functions. It emits and receives co-centered and co-directional optical (green) and ultrasound (purple) beams to facilitate communication and ranging.

Challenges & Motivation

Unmanned Underwater Vehicles (UUVs) or Autonomous Underwater Vehicles (AUVs) are very important tools for many applications. However, a significant and fundamental challenge faced by today's AUVs is communication and perception in the underwater environment. Traditional devices are bulky and have low spatial resolution in ranging and mapping tasks. Acoustic communication is slow in speed. Laser-based communication can achieve high speed, but requires direct light of sight. Therefore, there is no effective way to tightly coordinate a group of AUVs. The development of the PAIR device is expected to bring many challenges and opportunities into the field of AUVs. Recent progress in MEMS, sensors, embedded systems, and networked robots make it possible to combine interdisciplinary expertise to overcome these hurdles.

Scientific Impact

The PAIR devices can enable us to develop unique communication and perception capabilities: 1) The sonar signals can assist AUVs within range to find each other and align laser beams to pair laser transceivers for high speed communication (Fig. 2a); 2) The dual modal signals can enhance underwater terrain mapping due to the complementary nature of signal properties. The new communication and perception capability will allow a group of AUVs to perform collaborative tasks in the underwater environment (Fig. 2b); 3) An array of PAIR devices can also be used as bumper-mounted sensors to facilitate autonomous driving in poor weather conditions (Fig. 2c).

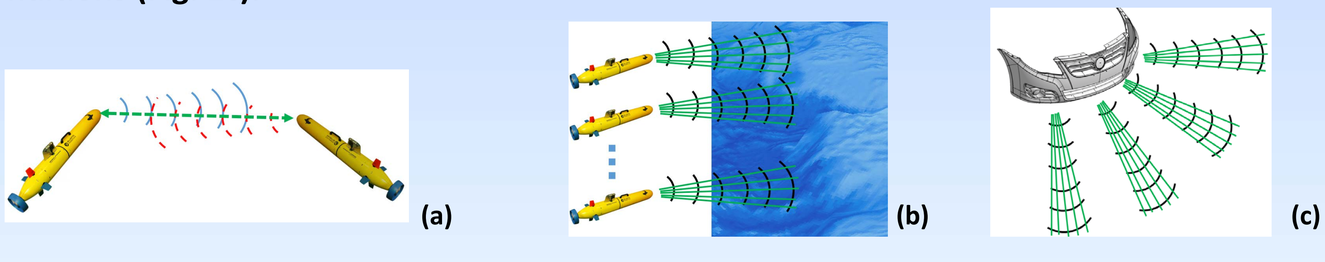

Fig. 2 Three new AUV communication and ranging functions enabled by the PAIR device: (a) Ultrasound assisted inter-vehicle optical communication; (b) Coordinated ranging and mapping by an AUV team; and (c) Dual modal obstacle detection and mapping for autonomous driving.

Solutions

The proposed system architecture for the PAIR device is shown in Fig. 3a, which consists of three functional subsystems: optical (green), ultrasound (blue), and beam steering (orange). As a key component of the PAIR device development, the optical-acoustic frontend module serves three main functions: optical transception, ultrasound transception, and co-centered and co-directional beam steering. A prototype optical-acoustic front end module has been designed, fabricated, and tested (Figs. 3b and 3c). The test results show that the optical-acoustic front end module is capable of transmitting, receiving and steering co-centered and co-directional laser and ultrasound beams under water (Figs. 3d and 3e). This work builds a technical foundation and forms the first step for the development of the proposed PAIR device.

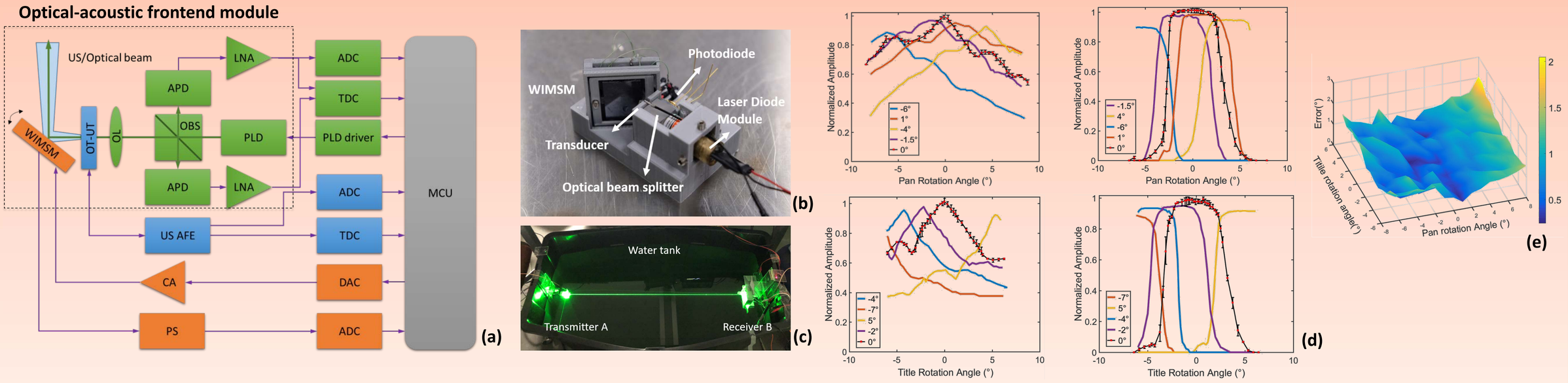

Fig. 3 (a) The proposed system configuration of the PAIR device; (b) A fabricated prototype of the optical-acoustic frontend module; (c) The testing setup under water; (d) The received ultrasound and laser signals at different pan and tilt angles; and (e) The misalignment of ultrasound and optical beams at different pan and tilt angles.

Broader Impacts

The project will benefit a wide range of AUV applications such as oil platform inspection, nature conservation, environment protection, public safety, search & rescue, etc. The research and development results will be disseminated to scientists, students, underrepresented groups, and the public.

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