Case Study: Photoacoustic Imaging of Hand Vasculature Using the Verasonics Vantage system

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Purpose: Image vasculature in the human palm

Major system components:

- Verasonics Vantage 128 system: 128 transmit and 128 receive channels
- Continuum Surelite SLIII-10 laser: 10 Hz, 10 ns pulse duration, 1064 nm output at up to 850 mJ.
- ATL/Philips L7-4 array: 128 elements, 5 MHz central frequency
- Dolan Jenner optical fiber bundle (dual branch line lights): One circular input and two line outputs
- Agilent 33250A function generator

Experimental procedure:

1. **Setup connections between Vantage 128 and Continuum laser**
   - Connect the laser, function generator, and the Vantage 128 according to the following diagram
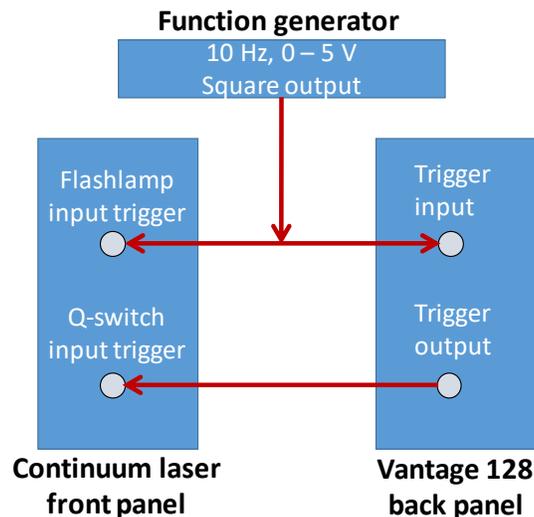

Figure 1: Schematic diagram of the connection between laser and Vantage 128.

- The function generator will output 10 Hz TTL as the master clock.
- Both the laser flashlamp and Vantage 128 will be triggered by the falling edge of TTL signal (SeqControl(11).condition = 'Trigger_1_ Falling';).
- After 300 µs delay (flash2Qdelay = 300), Vantage 128 will output a signal to trigger the firing of Q-switch.
- This setup will allow precise synchronization of Vantage data acquisition and laser firing (jittering is less than 10 ns).

2. **Open and modify (as needed) the photoacoustic example code**
   - Open the example Photoacoustic acquisition code, located under \Misc\PhotoAcoustics, or, Examples.Biomedical/specialtyApplications/Photoacoustics. The code is written for L11-4, but can be used for other supported linear arrays by modifying the Trans.name.
   - Based on the signal intensity, photoacoustic gains can be adjusted through the following lines.
     ```
     RcvProfile(2).LnaGain = 24;
     RcvProfile(2).PgaGain = 30;
     RcvProfile(2).condition = 'immediate';
     ```

3. **Couple laser light into optical fiber bundle**
   - If the laser beam diameter is smaller than the fiber input diameter, shine the laser beam directly to the fiber input. Otherwise, use a convex lens to focus/shrink the laser beam.
   - The Dolan Jenner fiber bundle has two line outputs, each can be mounted to one side of the transducer array (**Figure 2**). The angle of the line outputs can be adjusted to focus at around 25 mm, which is also the acoustic focus of L7-4 transducer.
   - To ensure laser safety, the intensity of laser beam on object surface needs to be quantified. This can be done by using a ruler to measure the beam diameter and a power meter to measure the total energy. For visible light (400 nm to 700 nm), American National Standards Institute (ANSI) defines a maximum permissible exposure of 20 mJ/cm^2. For near infrared lights, the permissible exposure ranges from 20 to 100 mJ/cm^2 (wavelength dependent). The actual intensity needs to be determined out from the ANSI publication.

4. **Set up the hand imaging system**
   - Assemble the system as shown in the **Figure 2**.
   - The transducer head and fiber output will be immersed in water.
   - The water tank will have an opening at the bottom, which will be sealed by a thin plastic film.
   - The laser output will trigger data acquisition in the Verasonincs system.
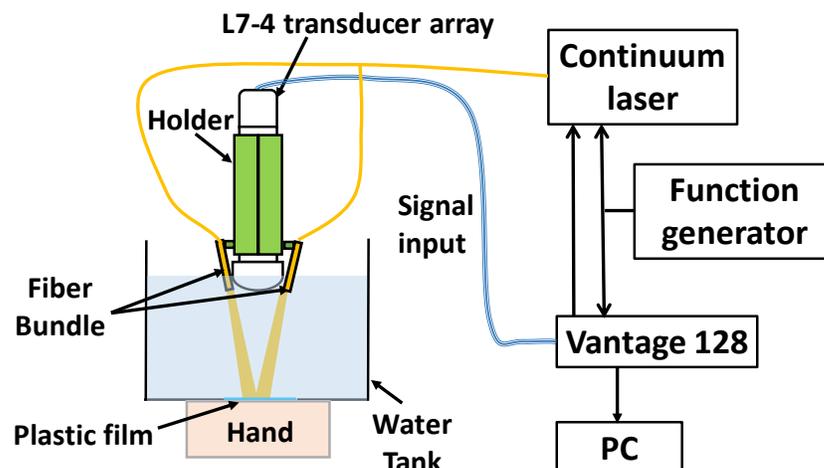   - For 3D imaging, the transducer and fiber bundles can be mounted on a linear translation stage.

Figure 2: Schematic diagram of the photoacoustic hand imaging setup.

5. Imaging procedure (IRB approval is needed before conducting this experiment)

- Place the subject's hand underneath the water tank and couple it with ultrasound gel. The distance between hand and probe can be around 25 mm (acoustic focus of the array).
- Adjust the laser to the desired power and turn it on.
- Run the example code. Dual-modal photoacoustic and ultrasound images should show up on the screen.
- Adjust the TGCs, transmit voltage and color settings to change the displayed contrast and signal strength. With a water bath standoff, the Speed of Sound parameter can be lowered from the default 1540 m/s to improve focusing through water.
- The program can be terminated at any time and the data will be saved in the workspace as ImgData (contains reconstructed ultrasound and photoacoustic images) and RcvData (contains the raw ultrasound and photoacoustic data). The following figure shows exemplary raw and reconstructed photoacoustic images.
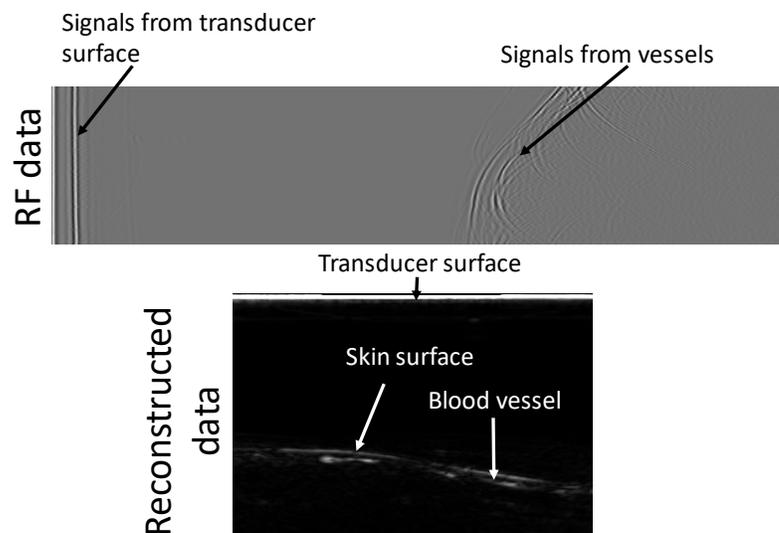

Figure 3: Raw and reconstructed photoacoustic images retrieved from Rcvdata and Imgdata, respectively.