

Progress Towards a Multi-modal Capsule Endoscopy Device Featuring Microultrasound Imaging

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Current clinical standards for endoscopy in the gastrointestinal (GI) tract combine high definition optics and ultrasound imaging to view the lumen superficially and through its thickness. However, these instruments are limited to the length of an endoscope and the only clinically available, autonomous devices able to travel the full length of the GI tract easily offer only video capsule endoscopy (VCE). Our work seeks to overcome this limitation with a device ("Sonopill") for multimodal capsule endoscopy, providing optical and microultrasound (μ US) imaging and supporting sensors(1).

μ US transducers have been developed with multiple piezoelectric materials operating across a range of centre frequencies to study viability in the GI tract. Because of the combined constraints of μ US imaging and the low power / heat tolerance of autonomous devices, a hybrid approach has been taken to the transducer design, with separate transmit and receive arrays allowing multiple manufacturing approaches to maximise system efficiency. To explore these approaches fully, prototype devices have been developed with PVDF, high-frequency PZT and PMN-PT composites, and piezoelectric micromachined ultrasonic transducer arrays. Test capsules have been developed using 3D printing to investigate issues including power consumption, heat generation / dissipation, acoustic coupling, signal strength and capsule integrity. Because of the high functional density of the electronics in our proposed system, application specific integrated circuits (ASICs) have been developed to realise the ultrasound transmit and receive circuitry along with white-light and autofluorescence imaging with single-photon avalanche detectors (SPADs).

The ultrasound ASIC has been developed and the SPAD electronics and optical subsystem have been validated experimentally. The functionality of various transducer materials has been examined as a function of frequency and ultrasound transducers have been developed to operate at centre frequencies in the range 15 - 50 MHz. Ex vivo testing of porcine tissue has been performed, generating images of interest to the clinical community, demonstrating the viability of the Sonopill concept.