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Combined optical and acoustical characterization of single ultrasound contrast agent microbubbles

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Contrast enhancement in medical ultrasound imaging is provided by the non-linear characteristics of coated microbubbles used as Ultrasound Contrast Agents (UCA). Optical time-resolved observations of the UCA microbubble dynamics have revealed new non-linear bubble behavior such as "compression only" and "thresholding" behavior. Up to now, the contributions of such behavior to the non-linear acoustic response of UCA microbubbles is not known. Theoretically, the sound emission of an oscillating microbubble is derived from the unsteady Bernoulli equation and mass conservation assuming incompressible and irrotational flow. An experimental validation of this relation between the radial dynamics and the sound emission of a microbubble is not straightforward. We present a combined optical and acoustical setup to characterize individual BR-14 (Bracco Research S.A., Geneva, Switzerland) UCA microbubbles. The bubbles were isolated in a capillary fiber by an active flow control. During insonation the radial response of the single microbubble was recorded with the Brandaris ultra high-speed camera while the resulting acoustic response was measured with an accurately calibrated sensitive transducer. The sound emission calculated from the measured radius-time curves gives excellent quantitative agreement with the directly measured sound emission for both the linearly oscillating microbubbles and bubbles displaying "compression-only" and "thresholding" behavior, which indeed resulted in a strong non-linear sound emission.