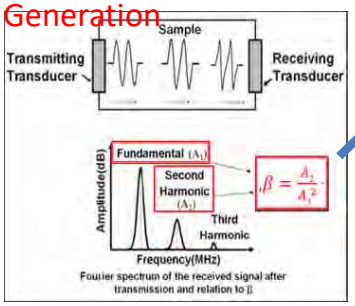
Evaluation of Fatigue Damages in Aluminum Plates by Nonlinear Ultrasonic Lamb Wave Observed by PS-FBG

Background

In the field of non-destructive evaluation, conventional linear ultrasonic methods that use linear amplitude and/or phase variations of reflected, transmitted or scattered ultrasonic waves are effective to detect opened cracks in solid materials. However, their sensitivity is not enough to detect closed cracks. Hence, nonlinear ultrasonic methods have been developed for evaluation of closed cracks at the early stage of their progresses.

Nonlinear Ultrasonics

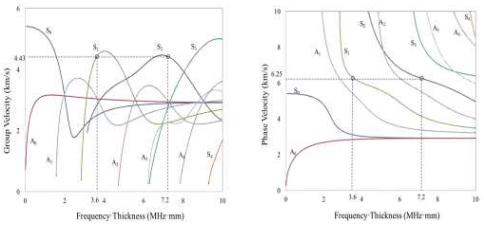
High Generation Harmonic



(Kyung-Young J., INT J PRECIS ENG MAN, 10, 2009, 123-135.)

Nonlinearity

β is a **nonlinear parameter** defined by the ratio of **second harmonic amplitude** and **power of fundamental**

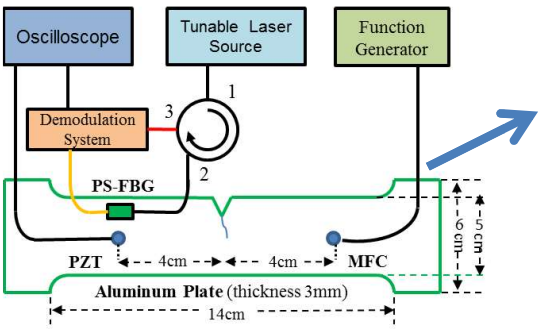


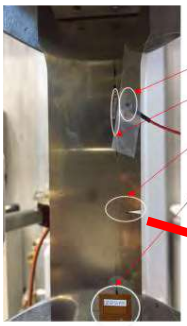
Fundamental mode and second harmonic mode share the same phase & group velocities

Second harmonic waves will be increased

Energy can be transferred between these two modes as it propagates

Experiment





PZT
PS-FBG
Crack
MFC actuator
(Micro Fiber Composite)

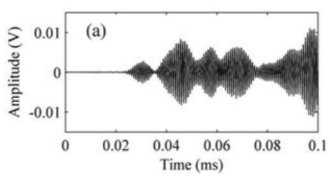
Fatigue test on an aluminum plate to generate closed crack in the plate.

Crack came out 54000 cycles | Grew up | Final state 110000 cycles

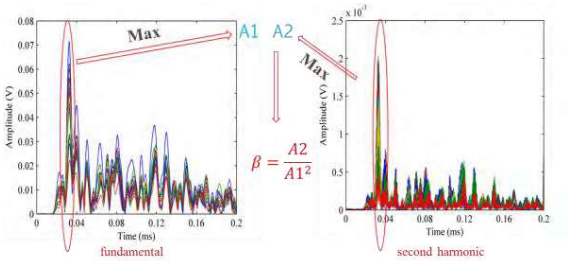
A PS-FBG sensor was bonded on the surface as an ultrasonic receiver
A PZT film actuator (MFC actuator) was used as an ultrasonic generator

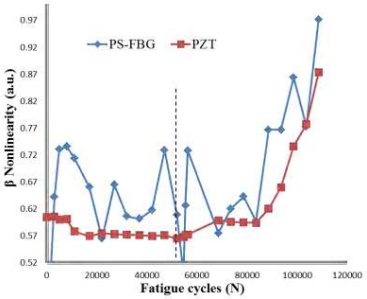
Data Processing

Time-domain signal ⇒ Continuous wavelet transform ⇒ Extract fundamental & second harmonic components ⇒ Calculate nonlinearity β ⇒ Plot



Waveform received in the PS-FBG before the fatigue loading





Conclusion

Nonlinear ultrasonic Lamb wave received in PS-FBG is effective to evaluate the progress of closed cracks in aluminum plates.