Study by means of liquid side acoustic barrier of the influence of leaky Rayleigh waves on bounded beam reflection

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The Schoch effect in ultrasonics, when sound is incident at the Rayleigh angle on a liquid-solid interface, consists of a forward beam displacement of the reflected beam, usually accompanied by a null strip in between the specular portion and the nonspecular reflected beam portion. It is a widely accepted idea that the effect is caused by reflected sound in combination with a sound field emitted by leaky Rayleigh waves. The current work presents an experimental technique to separate and investigate both fields separately by applying an acoustic barrier. The experiments are based on acousto-optic Schlieren photography. © *2008 American Institute of Physics*.
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Leaky Rayleigh waves are well-known elliptically polarized surface waves on the surface of a solid immersed in a liquid; their properties have been well documented in numerous reports.[1–9] These waves originate from earthquakes (geology), laser pulses (laser ultrasonics), surface acoustic wave devices (acoustic filters), diffraction phenomena (corrugated surfaces), or simply by a bounded beam impinging a smooth solid at the Rayleigh angle. The latter situation results in the Schoch effect which is a forward displaced reflected beam,[10,11] usually accompanied by a nullstrip, separating a specular beam portion from a nonspecular beam portion.[12] It is widely accepted that the formation of a specular and a nonspecular beam is initiated by the generated leaky Rayleigh waves, but the ultimate experimental proof of this physical effect has never been shown. The reason is that the appearance of two reflected beams is a secondary effect caused by interference between a sonic field directly reflected from the interface and a leaky sound field caused by the Rayleigh waves. This makes the two fields hard to separate.

In what follows we present an experimental setup to make this separation of the leaky field from the reflected field possible. It will be shown that the technique enables experiments that provide evidence that the nonspecular beam mainly constitutes the leakage field caused by Rayleigh waves and is not a side effect of a scattering phenomenon at the Rayleigh angle of incidence.

The idea is to place an acoustic barrier on a thick glass substrate, as in Fig. 1. The barrier consists of two thin microscope slides with air in between. This practically prevents, through the acoustic impedance mismatch, sound from penetrating through the barrier and ensures that whatever is transmitted must be transmitted through the glass substrate in the form of Rayleigh waves. Schlieren photography is used to visualize the sound fields.

At the Rayleigh angle, the Schoch effect (and the null strip) is observed, as shown in Fig. 2. The configuration of the transducer direction and distance to the plate are maintained during subsequent experiments. Three situations are studied: the sound barrier positioned "out of reach," "in the incident sound field," or "in the reflected sound field."

If the sound barrier is placed in the middle of the nonspecular reflected beam portion (i.e., the lobe on the right), as in Fig. 3, then the outer part of the second lobe remains. The presence of sound behind the barrier, where the nonspecular beam portion would have appeared without barrier, indicates that the nonspecular beam mostly consists of sound re-emitted by leaky Rayleigh waves as no sound impinges the solid behind the barrier. Positioning of the sound barrier further to the left produces Fig. 4, resulting in the appearance of the leakage field completely separated from the directly reflected sound beam.

The experiments with sound barrier show that the leakage field exists and coincides with the spatial area spanned by the resulting "reflected" sound beam in the absence of a sound barrier. The leakage field is caused by Rayleigh waves as they are the only waves capable of passing through

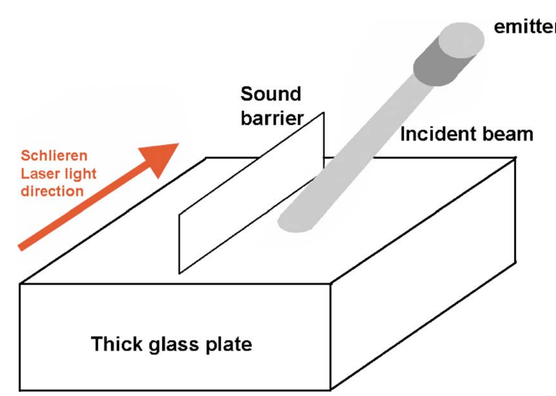

FIG. 1. (Color online) Schematic of experimental setup: sound incident on the right side generates Rayleigh waves that tunnel through vertical acoustic barrier.

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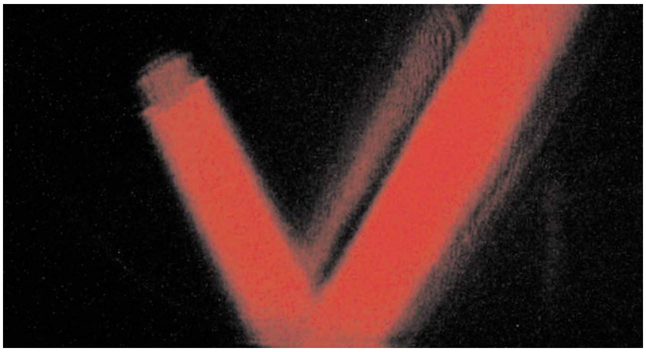

FIG. 2. (Color online) Acousto-optic schlieren picture of the Schoch effect (accompanied by null strip in between specular and nonspecular reflected beams) in the absence of an acoustic barrier.

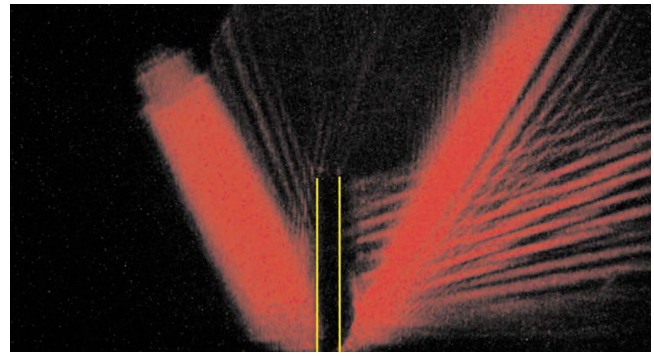

FIG. 4. (Color online) Similar to Fig. 3 with bounded beam coinciding with null strip base.

(more precisely "underneath") the sound barrier.

The reported experiments finally show conclusive experimental evidence of what has been "assumed" for many years, namely, that the Schoch effect and the null strip when bounded beams are incident at the Rayleigh angle, are caused by the superposition of directly reflected sound and sound re-emitted by leaky Rayleigh waves. The experimental proof presented in this letter ends a long discussion held in ultrasonics whether the Schoch effect is merely a scattering effect (with phase shifts and beam displacements) or is a recombination of a reflected field with a leaky field.

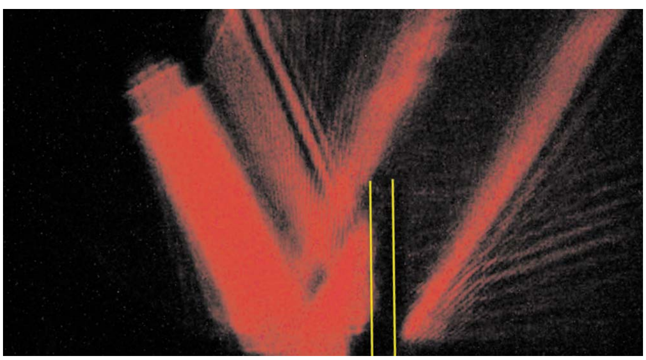

FIG. 3. (Color online) Similar to Fig. 2 with the spot of incidence near to sound barrier (indicated by vertical lines on the figure).

[1] M. A. Breazeale, L. Adler, and L. Flax, J. Acoust. Soc. Am. **56**, 866 (1974).
[2] M. A. Breazeale, L. Adler, and G. W. Scott, J. Appl. Phys. **48**, 530 (1977).
[3] J. M. Claeys and O. Leroy, J. Acoust. Soc. Am. **72**, 585 (1982).
[4] M. Debilly and I. Molinero, J. Acoust. Soc. Am. **83**, 1249 (1988).
[5] N. F. Declercq, A. Teklu, M. A. Breazeale, R. Briers, O. Leroy, J. Degrieck, and G. N. Shkerdin, J. Appl. Phys. **96**, 5836 (2004).
[6] T. Kundu, J. Acoust. Soc. Am. **83**, 18 (1988).
[7] W. G. Neubauer and L. R. Dragonet, J. Appl. Phys. **45**, 618 (1974).
[8] T. D. K. Ngoc and W. G. Mayer, J. Acoust. Soc. Am. **67**, 1149 (1980).
[9] J. Pott and J. G. Harris, J. Acoust. Soc. Am. **76**, 1829 (1984).
[10] A. Schoch, Acustica **2**, 1 (1952).
[11] A. Schoch, Acustica **2**, 18 (1952).
[12] W. G. Neubauer, J. Appl. Phys. **44**, 48 (1973).