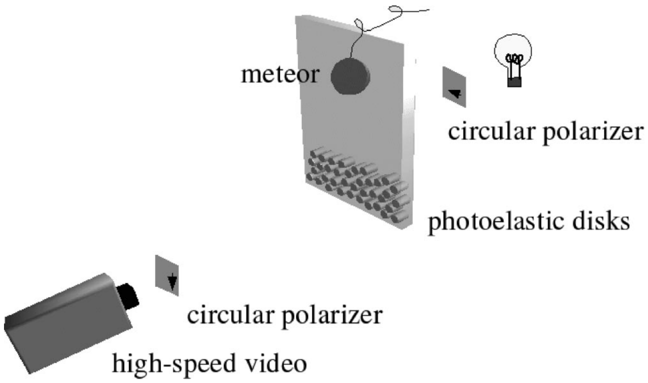

FIG. 1. Schematic drawing of apparatus, not to scale.

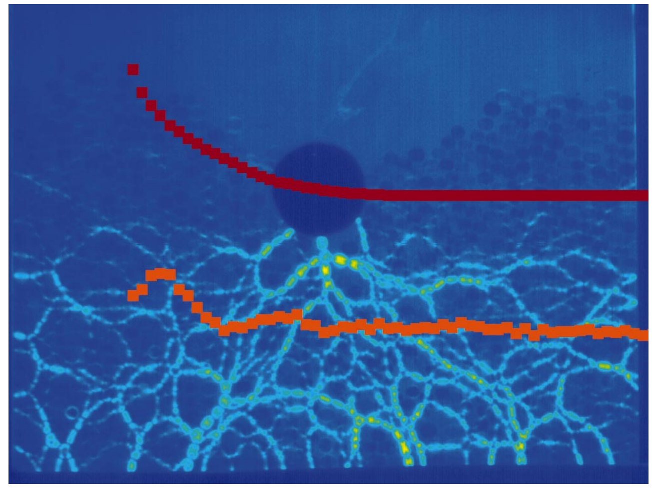

FIG. 2. (Enhanced online). False-color image of force chains during meteor impact: blue is weak force, green/yellow is strong. Dark circle in center of image is the meteor, and small circles are the photoelastic particles comprising the impact bed. Upper (red) curve: time trace of meteor position. Lower (yellow) curve: time trace of the force stored in photoelastic disks. Duration of curves is 0.28 s, with points measured at 210 Hz.

Dynamics of meteor impacts

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The morphology of meteor craters has historically been studied via static analysis, after the fact, of what are highly dynamic impact events. As such, there are long-standing questions about the process through which a meteor comes to rest and forms a crater. There has been a great deal of recent interest in this question, using both three-dimensional and two-dimensional lab-scale analogs of meteor impacts to provide controlled experiments.[1] The experiments shown in this video directly visualize the forces generated in the impact bed through the use of photoelastic particles.

The experimental apparatus is shown in Fig. 1. Photoelastic particles of diameter 0.74 cm (800 particles) and 0.90 cm (125 particles) and thickness 0.64 cm were loosely sandwiched between sheets of transparent Plexiglas in a region 33 cm wide. The bidisperse mixture is used to suppress crystallization. We prepared the bed before each run by tipping the apparatus and allowing the particles to rain back down. When visualized through crossed circular polarizers, contact forces within the photoelastic particles appear as bright streaks, where larger intensity gradients correspond to larger forces. We calibrate the system using known forces to determine the correspondence between the mean squared gradient and the total force in the network. Details ofthe method are available in Ref. 2. A "meteor" of diameter 5 cm was released from rest at a height of ≈30 cm above the bed. Data were collected during the impact using high speed video (210 Hz) and are shown in the movie slowed by 7 and 70 times. The images are displayed using false color to emphasize the dynamics of the force chains during the impact.

Figure 2 shows a snapshot of force chains during a meteor collision overlaid with graphs of meteor position $x(t)$ and total bed force $F(t)$ determined from each frame in the series. (See http://www.phy.duke.edu/research/ltb/movies/meteor.mov for the video.) Remarkably, while the meteor decelerates monotonically, there are damped force oscillations within the impact bed. The minima of $F(t)$ correspond with fluidization of the bed in the region of the meteor. After the impact, the meteor is at rest within the bed, and the particles have been displaced to form a crater rim.

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[1]M. P. Ciamarra, A. H. Lara, A. T. Lee, D. I. Goldman, I. Vishik, and H. L. Swinney, Phys. Rev. Lett. **92**, 194301 (2004); M. Sandtke, D. van der Meer, M. Versluis, and D. Lohse, Phys. Fluids **15**, S7 (2003); A. M. Walsh, K. E. Holloway, P. Habdas, and J. R. de Bruyn, Phys. Rev. Lett. **91**, 104301 (2003); J. S. Uehara, M. A. Ambroso, R. P. Ojha, and D. J. Durian, Phys. Rev. Lett. **90**, 194301 (2003).
[2]D. Howell, R. P. Behringer, and C. Veje, Phys. Rev. Lett. **82**, 5241 (1999).

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