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Ultrasonic monitoring of dendritic solidification under a pressure gradient

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Inner core crystallisation is unconventionnal in many respects: the solidification is very slow, thermal gradients are weak and adverse, the newly formed solid being hotter than the adjacent liquid. Theoretical works suggest that in such conditions, a sizeable dendritic layer may have developped in the upper part of the inner core, where convection and compaction (i.e. gradual collapse of the mush under its own weight) are expected to play key roles.

We designed and build an experimental set-up devoted to the study of the crystallisation of a model material, camphene, under a solidification regime similar to that of the inner core, i.e. freezing resulting from a gradual cooling in a pressure field. A camphene sample is solidified in a lab centrifuge, where the pressure gradient induced by the centrifuge acceleration in the sample is high enough to significantly affect the melting temperature. When slowly decreasing the temperature in the sample, the crystallisation initiates in the high pressure end of the sample and propagates toward the low pressure end. The high apparent gravitational field promotes compaction in the mush. The solidifying material is scanned in situ with ultrasounds, allowing us to investigate the variations of ultrasound velocity and attenuation in the liquid, mush and solid domains. The dendritic zone shows a frequency dependant reflectance (with a maximum reflectance at a wavelength close to the interdendritic spacing) which is reminiscent of the so-called acoustic band gap observed by acousticians in periodic scattering arrays.