snow microstructure. As a consequence, shear deformation reduces strength as bonds are broken, but densification increases strength as higher density leads to an increased number of contacts. The formation of bonds between adjacent ice granules can be envisaged as a thermodynamically driven sintering process [3] which leads to strengthening of snow over time (ageing) [4]. The interplay between strain softening and age hardening leads to ductile behavior at low strain rates, when broken bonds have sufficient time to re-form, and to quasi-brittle behavior at high strain rates when this is not possible. This transition can be observed both in pure shear [4] and in compressive deformation [5].

At intermediate strain rates where ageing and softening processes occur on the same time scale, complex spatio-temporal deformation patterns and oscillation phenomena may occur. Such phenomena are well documented in deformation of metals where they have been analysed under the generic term of *strain rate softening* instabilities [6, 7, 8] but have never been studied in snow or similar cohesive-granular materials. The present investigation presents the first experimental and computational investigation of spatio-temporal deformation oscillations in snow as observed in compression experiments which are carried out at strain rates that are borderline between the ductile and quasi-brittle deformation regimes.

2 Experimental method

Specimens of artificially produced dry snow with density $\rho = 370\,\mathrm{kg/m^{-3}}$ and mean grain size $\xi \approx$ 0.2mm were contained within a rectangular transparent container with Aluminium alloy side walls and a glass front and back. The specimens were compacted from above by an anvil moving at fixed rates of $1.125\,\mathrm{mm\,s^{-1}}$ and $5\,\mathrm{mm\,s^{-1}}$, thus providing nominal strain rates of $\dot{e}_{\rm ext} = 5.77 \times 10^{-3} s^{-1}$ and $2.56 \times 10^{-2} s^{-1}$. The experiments were carried out at a temperature of $T = -10°$C. During deformation, the driving force was recorded by a load cell located above the anvil. A 18 megapixel camera was located in front of the specimens with illumination provided by a flashgun and diffuser located behind the specimens. Images of the transmitted light were recorded at 0.25 s intervals. When the images are viewed, compacted areas become apparent as darker regions (Fig. 1, left). It was generally found that compaction occurs in a heterogeneous manner by motion of compaction fronts which separate regions of different density (Fig. 1, see also results section). To quantify this phenomenon in terms of displacements, each image series was analyzed using digital image correlation (DIC) software. Local strain and strain rate tensors were then calculated from the displacement fields. Further details of the experimental set-up are given in the Supplementary Material.