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Controlling and Exploring Quantum Matter at the Single Atom Level

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More than 30 years ago, Richard Feynman outlined the visionary concept of a quantum simulator for carrying out complex physics calculations. Today, his dream has become a reality in laboratories around the world. In my talk I will focus on the remarkable opportunities offered by ultracold quantum gases trapped in optical lattices to address fundamental physics questions ranging from condensed matter physics over statistical physics to high energy physics with table-top experiment.
For example, I will show how it has now become possible to image and control quantum matter with single atom sensitivity and single site resolution, thereby allowing one to directly image individual quantum fluctuations of a many-body system. Such ultrahigh resolution and sensitivity have also enabled us to detect 'Higgs' type excitations occurring at 24 orders of magnitude lower energy scales than in high energy physics experiments. Finally, I will show how the unique control over ultracold quantum gases has enabled the creation of negative temperature states of matter and thereby the realization of Bose-Einstein condensation at absolute negative temperatures.