Chapter 9
Summary and Outlook

In this thesis we have studied and exploited the interaction between terahertz frequency electric fields and laser excited Rydberg atoms in a hot caesium vapour. We have used caesium Rydberg atoms to perform terahertz electrometry and real-time terahertz field imaging and we have explored a terahertz-driven non-equilibrium phase transition in a Rydberg vapour. In developing the necessary experimental techniques we have investigated hyperfine quantum beats modified by an excited-state transition, and Rydberg optical bistability.

In the future the work presented here could be extended in many different directions. The mechanism for interaction between Rydberg atoms responsible for optical bistability still remains an open question. Using the monochromator to monitor the fluorescence of particular atomic decay channels as the Rydberg laser is scanned might reveal some more insight, particularly at low principal quantum number, n, where the fluorescence is strong and it is possible to resolve individual lines. In contrast, using a longer vapour cell might help investigate higher Rydberg states ($n \gg 30$). The stronger interactions of higher lying states require a lower number density, and so a longer vapour cell could be used to retain sufficient optical depth.

Throughout this thesis we focused on one particular terahertz-frequency transition (caesium $21P_{3/2} \rightarrow 21S_{1/2}$), but there are very many others to investigate. There are also several other options for immediately developing the terahertz imaging technique. Although the laser beam configuration used is this work leads to a convenient Rydberg EIT signal, it gives the minimum 3-photon Doppler shift for atoms moving along coaxial laser beams. Because the Doppler shift is responsible for velocity selection which reduces the motional blurring, it is reasonable to imagine that better resolution could be achieved with a different laser beam configuration, (all the lasers co-propagating would maximise the 3-photon Doppler shift). So far the imaging technique has only been demonstrated in 1-dimension, and so another immediate development could be to use the laser beams in a light-sheet configuration.Velocity selection could be achieved in both axes by crossing the excitation laser beams. The author hopes that this work represents the beginning of further terahertz-field detection and imaging with hot Rydberg Vapours.

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