I. INTRODUCTION

Polaritons in magnetic and dielectric media arise from coupling between the electromagnetic field and polarisations of the media[1]. A particularly interesting polariton is localised to the surface of a bounded material. Surface polaritons can display nonreciprocity, where the propagation frequency in one direction is different from the propagation in the opposite direction. If the propagation wavevector is $\vec{k}$, then nonreciprocity can be expressed in terms of frequency ω as $\omega\left(\vec{k}\right) \neq \omega\left(-\vec{k}\right)$. Numerous applications for nonreciprocal surface waves exist[2, 3] including recent developments for surface polariton optics[4, 5].

Magnon polaritons are coupled photon and magnetic excitations, and exist for simple ferromagnets[6, 7] and multisublattice magnets including antiferromagnets[8]. In the present work, we discuss surface modes for an interesting class of materials that are currently a focus of attention: magnetic multiferroics. Multiferroics display long range order and polarisable response in two or more aspects: elastic, dielectric and magnetic. The calculations presented here are illustrated using parameters appropriate for $BaMnF_4$, a material that has been modeled with a linear magnetoelectric coupling between the magnetic and dielectric subsystems. This material has two magnetic sublattices, and a canting angle between sublattice magnetisations results from magnetoelectric interaction[9–11].

Some properties of bulk polaritons in linear magnetoelectric coupled media have been calculated theoretically in Refs. 9 and 10, and surface modes have been examined in Refs. 12 and 13. To the best of our knowledge, until now dispersion relations in the presence of applied electric and magnetic fields have not been discussed, and explicit results for surface modes in $BaMnF_4$ have not been presented.

In this work, we show that nonreciprocity of magnetic polariton surface modes can be modified by application of an external magnetic field. We extend previous work by allowing magnetic sub-lattices to cant, and provide explicit results for surface and bulk modes on $BaMnF_4$. Our results are relevant for understanding and predicting microwave and infrared responses of ferroelectric/magnetic and multiferroic/magnetic multilayers[14, 15] and composites[16, 17]. In these types of heterostructures, it may be possible to achieve effective media with magnetoelectric properties and a range of material parameter values not possible in single phase multiferroics.

The paper is organised as follows. The field dependence of the magnetic canting angle