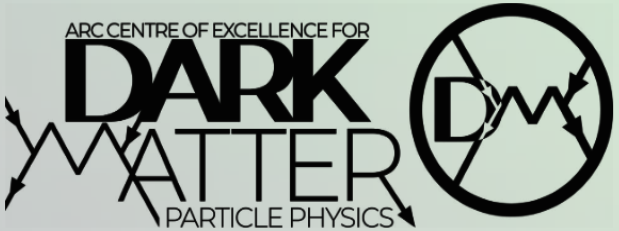
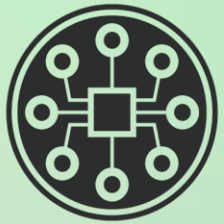
Precision Multi-mode Microwave Characterisation of Single Crystal Calcium Tungstate for Dark Matter Searches



THE UNIVERSITY OF WESTERN AUSTRALIA



EQUS
Australian Research Council Centre of Excellence for Engineered Quantum Systems

Elrina Hartman

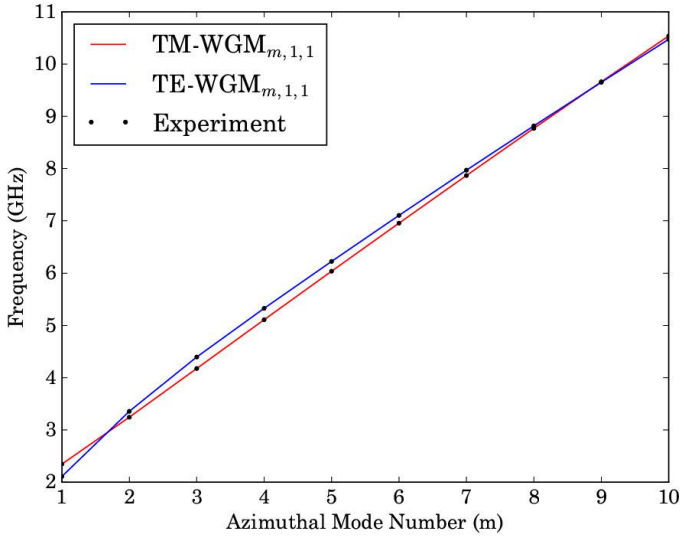
Supervisors: Michael Tobar, Maxim Goryachev, Ben McAllister

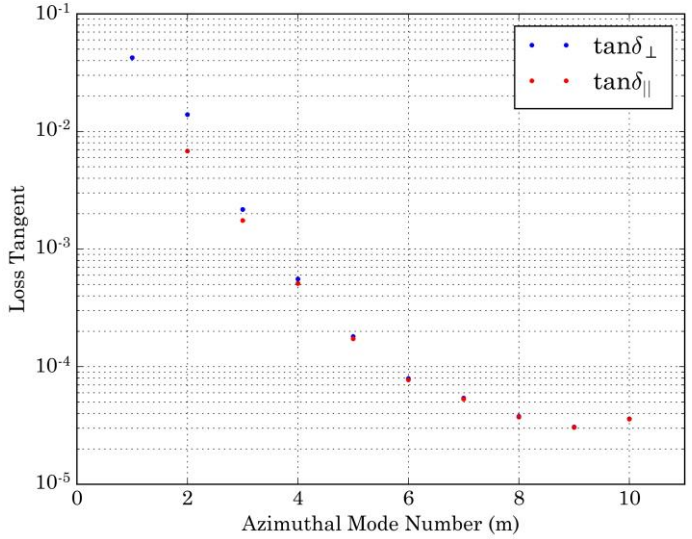
Dielectric Characterisation

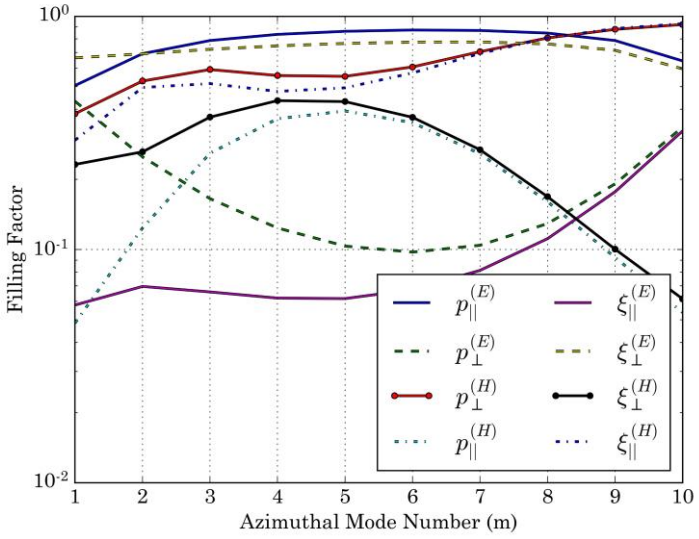
Permittivity at room temperature:

$\varepsilon_{\parallel} = 9.0249 \pm 0.0005$

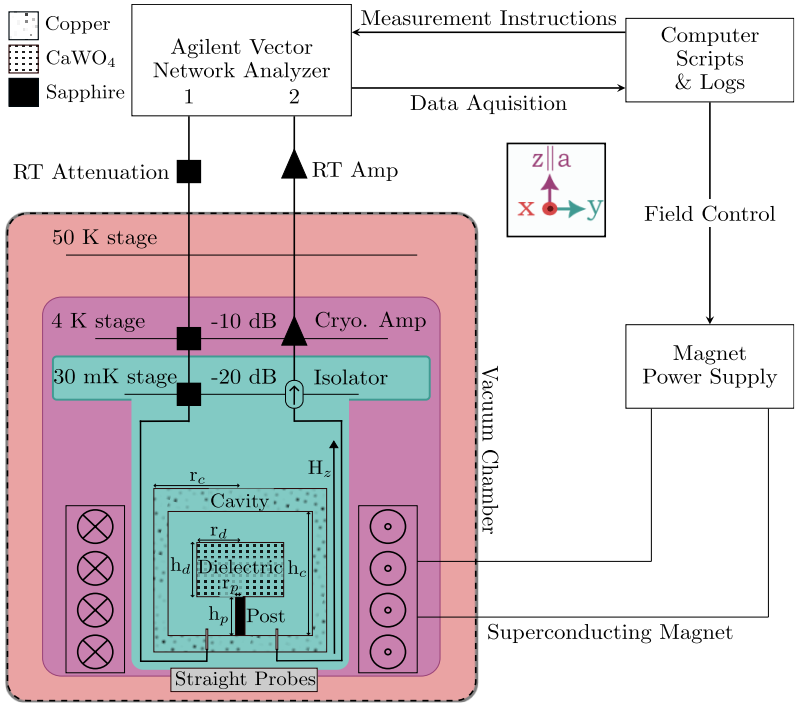
$\varepsilon_{\perp} = 10.737 \pm 0.0005$

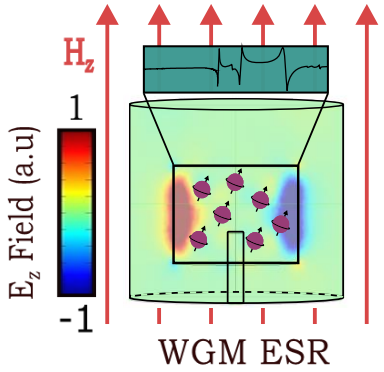






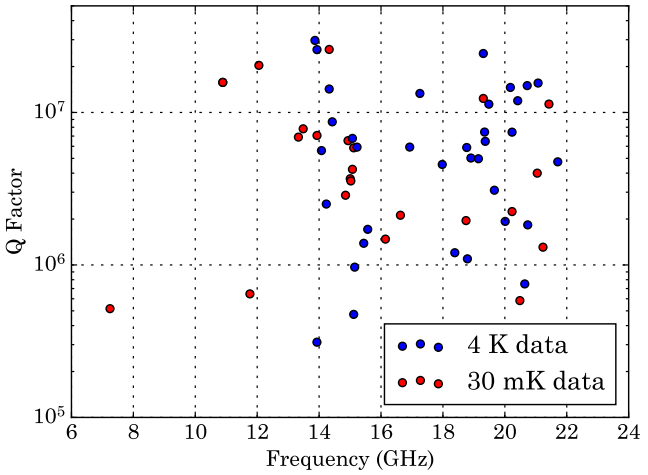
ESR Spectroscopy Methods



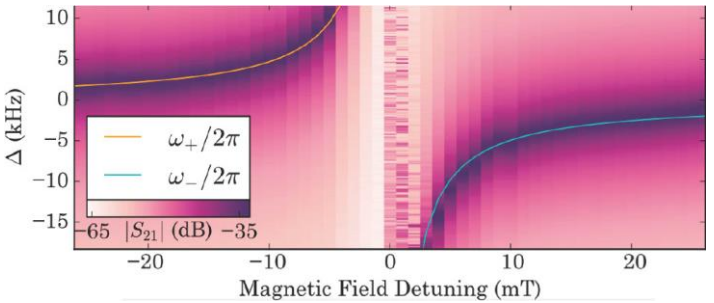


Dimensions of dielectrically loaded cavity resonator:

r_c=25 mm, h_c=40 mm
r_d=14.98 mm, h_d = 20 m
r_n=1.75 mm, h_n=14.5 mn

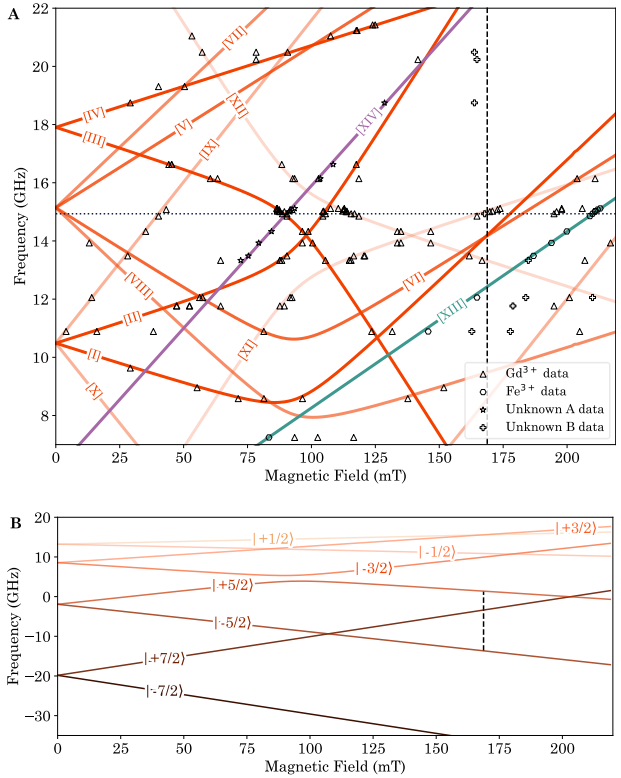


f_0 = 14.934048 GHz



$$\omega_{\pm} = \frac{1}{\sqrt{2}}\sqrt{\omega_s^2 + \omega_p^2 \pm \sqrt{\omega_s^4 - 2\omega_s^2\omega_p^2 + 4\Delta_{ps}\omega_s^2\omega_p^2 - \omega_p^4}}$$

ESR Spectroscopy Results



Species	ΔS_z	Line	ZFS (GHz)	Transition
$CaWO_4:Gd^{3+}$ $g_L = 1.99$	1	I	10.49	$\|+5/2\rangle \rightarrow \|+3/2\rangle$
		II		$\|-5/2\rangle \rightarrow \|-3/2\rangle$
		III	17.90	$\|+7/2\rangle \rightarrow \|+5/2\rangle$
		IV		$\|-7/2\rangle \rightarrow \|-5/2\rangle$
	2	V	15.14	$\|-5/2\rangle \rightarrow \|-1/2\rangle$
		VI		$\|+5/2\rangle \rightarrow \|+1/2\rangle$
	3	VII	15.14	$\|-5/2\rangle \rightarrow \|+1/2\rangle$
		VIII		$\|+5/2\rangle \rightarrow \|-1/2\rangle$
	4	IX	10.49	$\|-5/2\rangle \rightarrow \|+3/2\rangle$
		X		$\|+5/2\rangle \rightarrow \|-3/2\rangle$
	5	XI	0.0	$\|-5/2\rangle \rightarrow \|+5/2\rangle$
		XII	28.33	$\|+7/2\rangle \rightarrow \|-3/2\rangle$
$CaWO_4:Fe^{3+}$ $g_L = 4.3$	-	XIII	2.20	-
Unknown A $g_L = 7$	-	XIV	6.10	-

TABLE I. Properties of spin transitions calculated from the multi-mode spectroscopy results. Here, ΔS_z is the change in spin quantum number.

$$g = g_L \mu_B \sqrt{\frac{\mu_0 \omega_p n \xi_\perp}{4\hbar}}$$

where;
g_L is the Landé g factor,
μ_B is the Bohr Magneton,
$\hbar$ is the reduced Planck's constant,
$\xi_\perp$ is the perpendicular magnetic filling factor,
and μ_0 is the permeability of free space.

$n = 8.28 \pm 1.24 \times 10^{13}$ cm^{-3} which is on the order of ppb.

$$\mathcal{H} = g_L \mu_B H_z S_z + B_2^0 O_2^0 + B_4^0 O_4^0 + B_4^4 O_4^4 + B_6^0 O_6^0 + B_6^4 O_6^4$$