# Investigation of magnetic structure by spin-polarized scanning tunneling microscopy in $ErB_4$ tetraboride

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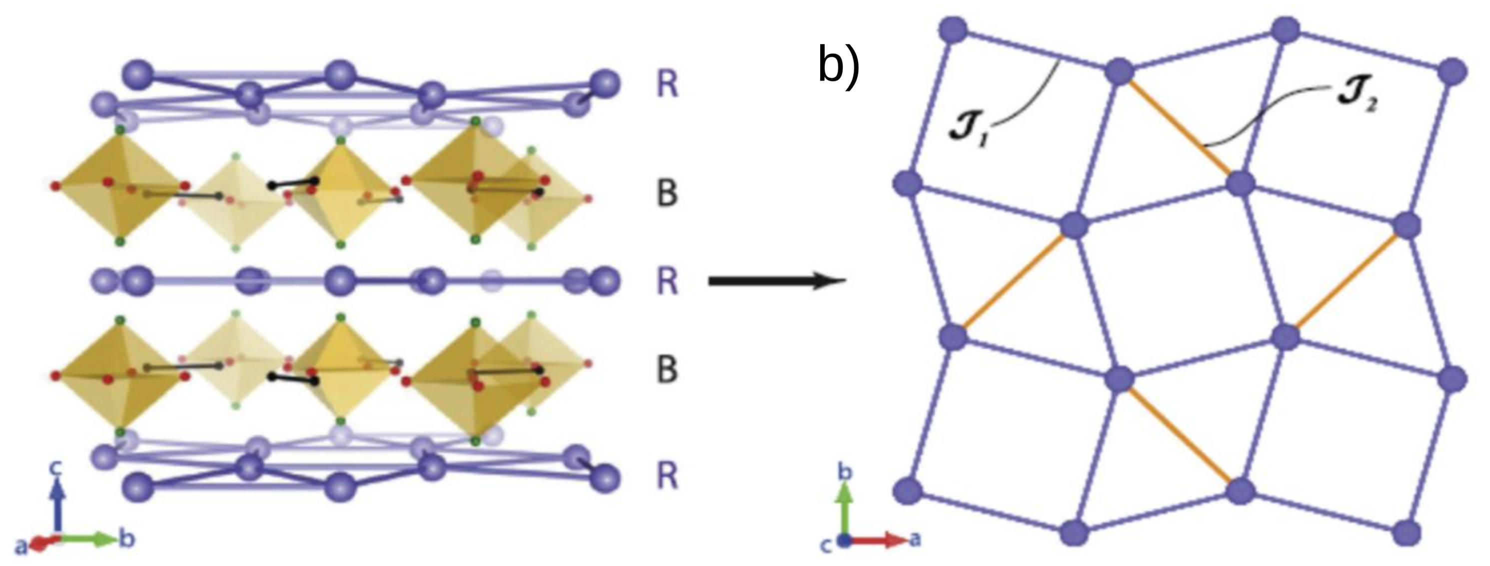
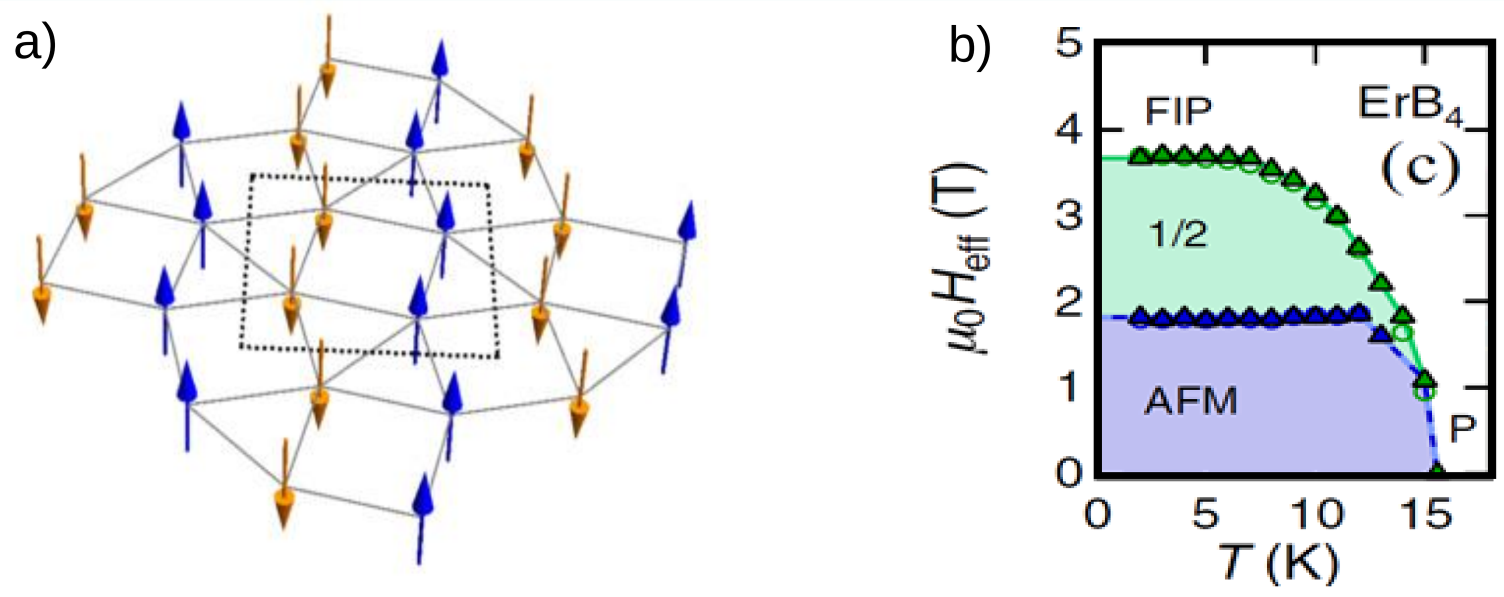
Rare earth tetraborides ($REB_4$) are known as 2D frustrated magnets on the Shastry-Sutherland lattice (SSL), where they form a structure of squares and equilateral triangles [1]. Moreover, at a critical magnetic fields and/or critical temperatures, these materials can transform from the antiferromagnetic to the ferrimagnetic state.
In this work, we compare the topography of the atomic structure with the possible topography of spin states in $ErB_4$ using a scanning tunneling microscope (STM). Measurements were performed at temperature of 1.2 K and in zero magnetic field as well as above the critical magnetic field of 2 T, using non-magnetic gold (Au) and a modified spin-polarized antiferromagnetic chromium (Cr) tips. The Fourier transformation of the topography at zero magnetic field with Au-tip reveals a lattice constant of $a \approx 7.02$ Å, which closely matches the value of 7.057 Å for $ErB_4$ [2]. At the same time, increasing the magnetic field above the critical value did not show any changes in the surface structure of the sample. Replacing the Au-tip by a Cr one, even at zero field, revealed magnetic stripes on the sample surface. The width of observed stripe domains of ≈ 21.41 Å was measured in the Fourier transformation of the topography, corresponding to a three-lattice constants-wide stripe. Moreover, the direction of the magnetic stripes is slightly rotated with respect to the atomic structure of the sample. However, scanning the topography at magnetic fields above the critical values, where the sample goes to the ferrimagnetic state, did not show any changes in the magnetic structure.

## Magnetic properties of $ErB_4$



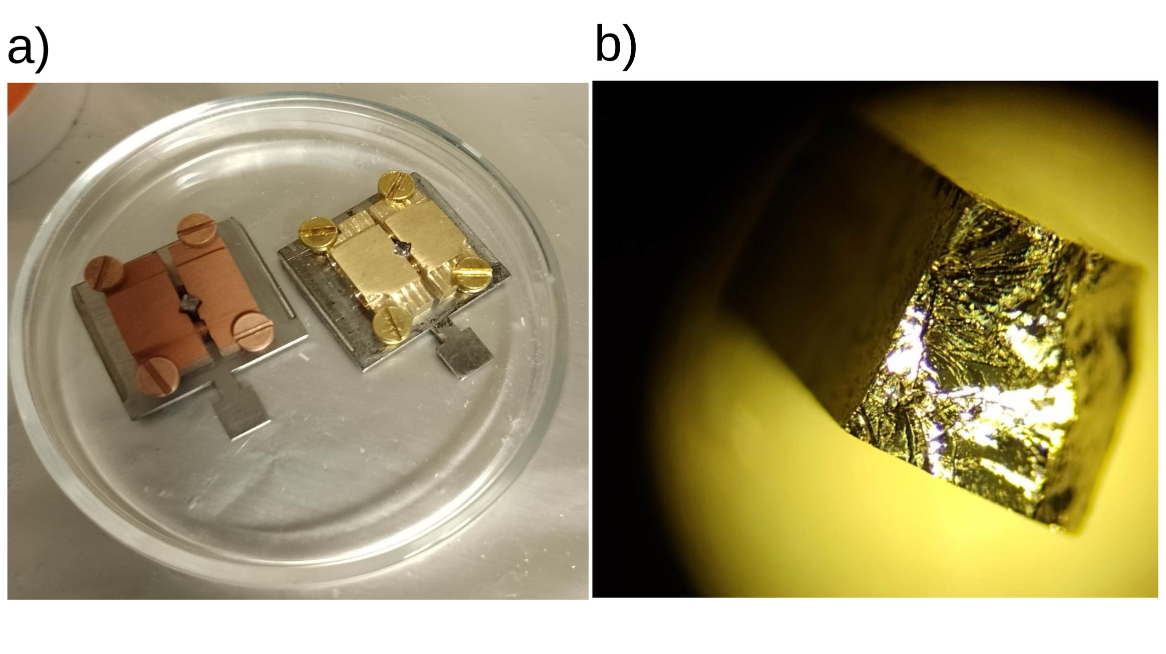

Crystal structure of REB-4 . The RE and B layers are labeled (a). The RE sublattice (perpendicular to c-axis) showing the frustrated Shastry-Sutherland lattice (b) [1].




Spin arrangement of the antiferromagnetic ground state in the Shastry–Sutherland lattice of $ErB_4$ (a). Phase Diagram of $ErB_4$ (b) [1].

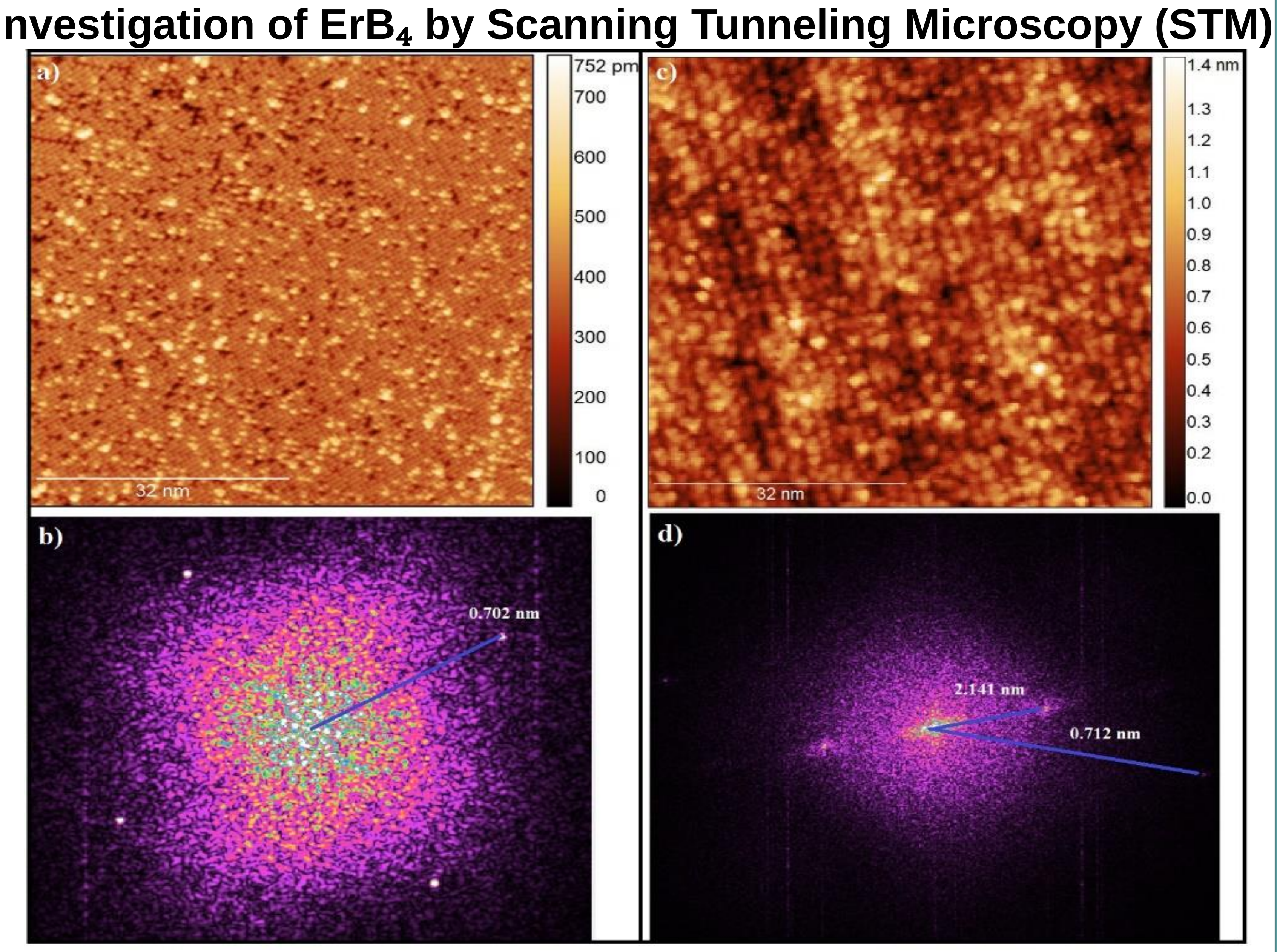
$ErB_4$ is an antiferromagnetic system in its ground state with the magnetic moment oriented along the c-axis. Due to strong Ising-type single-ion anisotropy, the f-electron moments are locked perpendicular to the Shastry–Sutherland lattice formed by erbium ions. Magnetic saturation in this direction is achieved at approximately $B_{Sc} \approx 4$. Perpendicular to the c-axis, saturation occurs at approximately $B_{Sab} \approx 14$ T. The Neel temperature, marking the transition from the antiferromagnetic to the ferrimagnetic state, is $T_N = 15{,}4$ K. In both directions of magnetization, a pronounced magnetization plateau is observed at half the saturation magnetization, arising from complex spin-flip processes. The lattice constants $a$ and $c$ for $ErB_4$ are 7,057 Å and 3,987 Å, respectively.

## The sample preparation for the experiment

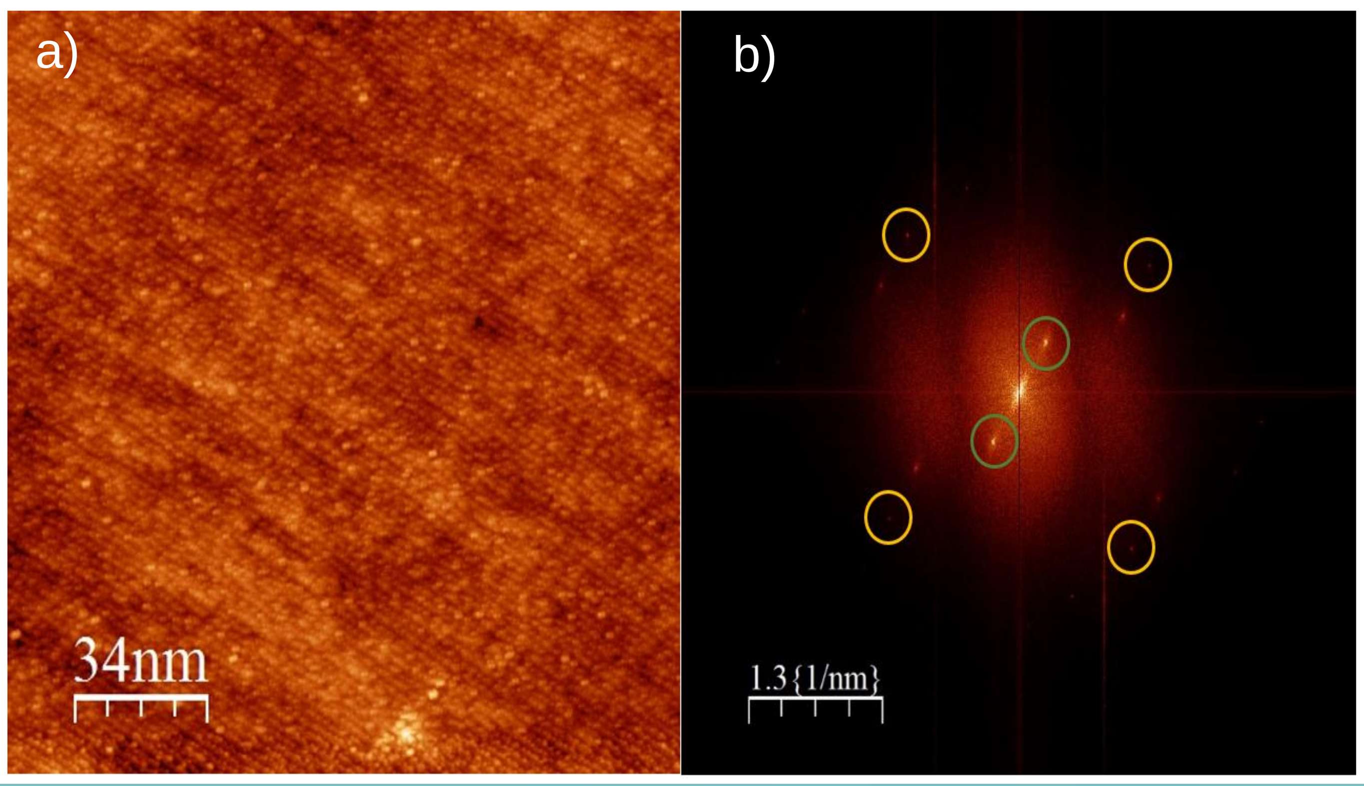



Sample preparation for **in-situ** UHV STM measurements. **In-situ** cleaved sample held in two 'clamps' (a). Surface of the **in-situ** cleaved sample under an optical microscope (b).

## Investigation of $ErB_4$ by Scanning Tunneling Microscopy (STM)




The topography of atomic (a) and magnetic stripe (c) structure of $ErB_4$ sample, scanned by using Au and Cr tips, respectively. The Fourier transformation reveals the lattice constants of 0.702 nm (b) and 2.141 nm (d), respectively.




STM topography(a) and FFT (b) at 2,5 T magnetic field using a Cr tip shows the lattice constants of 0.705 nm and 2.088 nm, respectively

## Conclusions

In this work, we investigated the atomic and magnetic structure of the $ErB_4$ surface using scanning tunneling microscop (STM):
1. Using a gold tip, we observed a surface structure with a lattice constant of 7.02 Å, which corresponds to the a-axis of $ErB_4$.
2. With a chromium tip, we observed a structure with a lattice constant of 21.41 Å, corresponding to magnetic stripes in the $ErB_4$ material.
3. Increasing the magnetic field up to 2.5 T — at which the sample transitions to a ferrimagnetic state — did not result in any observable changes in the surface structure.
The further studies of similar systems are required with upgrades of the measuring equipment.

**Acknowledgements:**

We acknowledge APVV-23-0226, VEGA 2/0034/24, DAAD-SAS-2023-02 and U.S. Steel Košice, s.r.o. for financial support.

**References:**

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[2] L. Ye, T. Suzuki, and J. G. Checkelsky, *Phys. Rev. B*, 95 (2017), 174405.

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