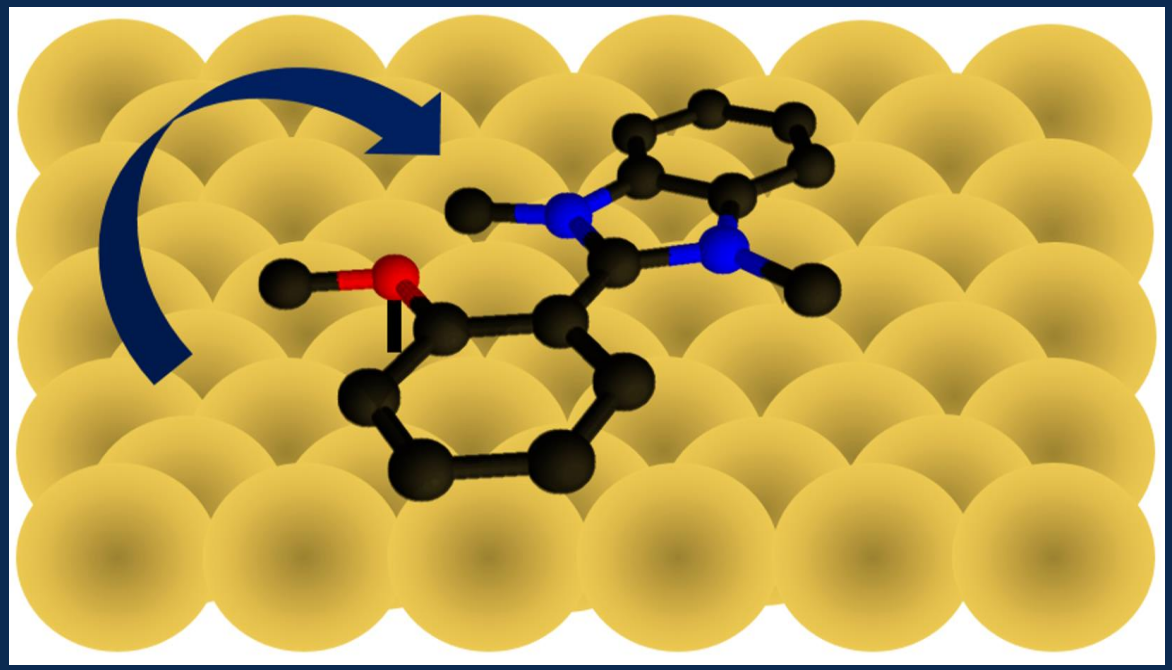
Our molecular rotor – o-MeO-DMBI on Au(111) (Measurements April 2018)



DMBI on Au(111)

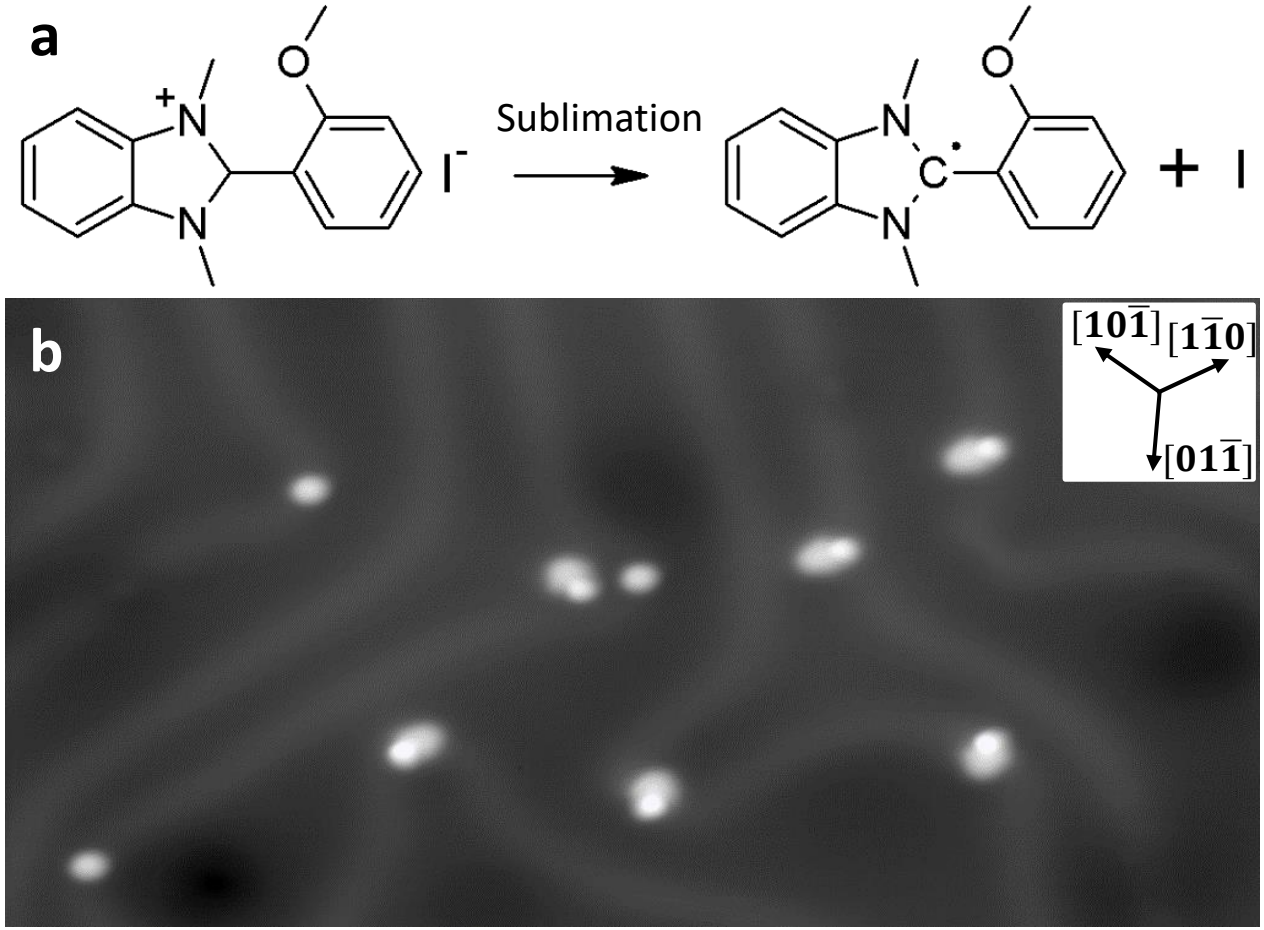


Figure 1. (a) Formation of the radical o-MeO-DMBI compound by evaporation and **(b)** overview image of a submonolayer of o-MeO-DMBI molecules on the surface. The inset shows the main crystallographic directions. (image size: 40 nm x 20 nm; V = -0.4 V; I = 60 pA)

DMBI on Au(111) – (Lateral Manipulation)

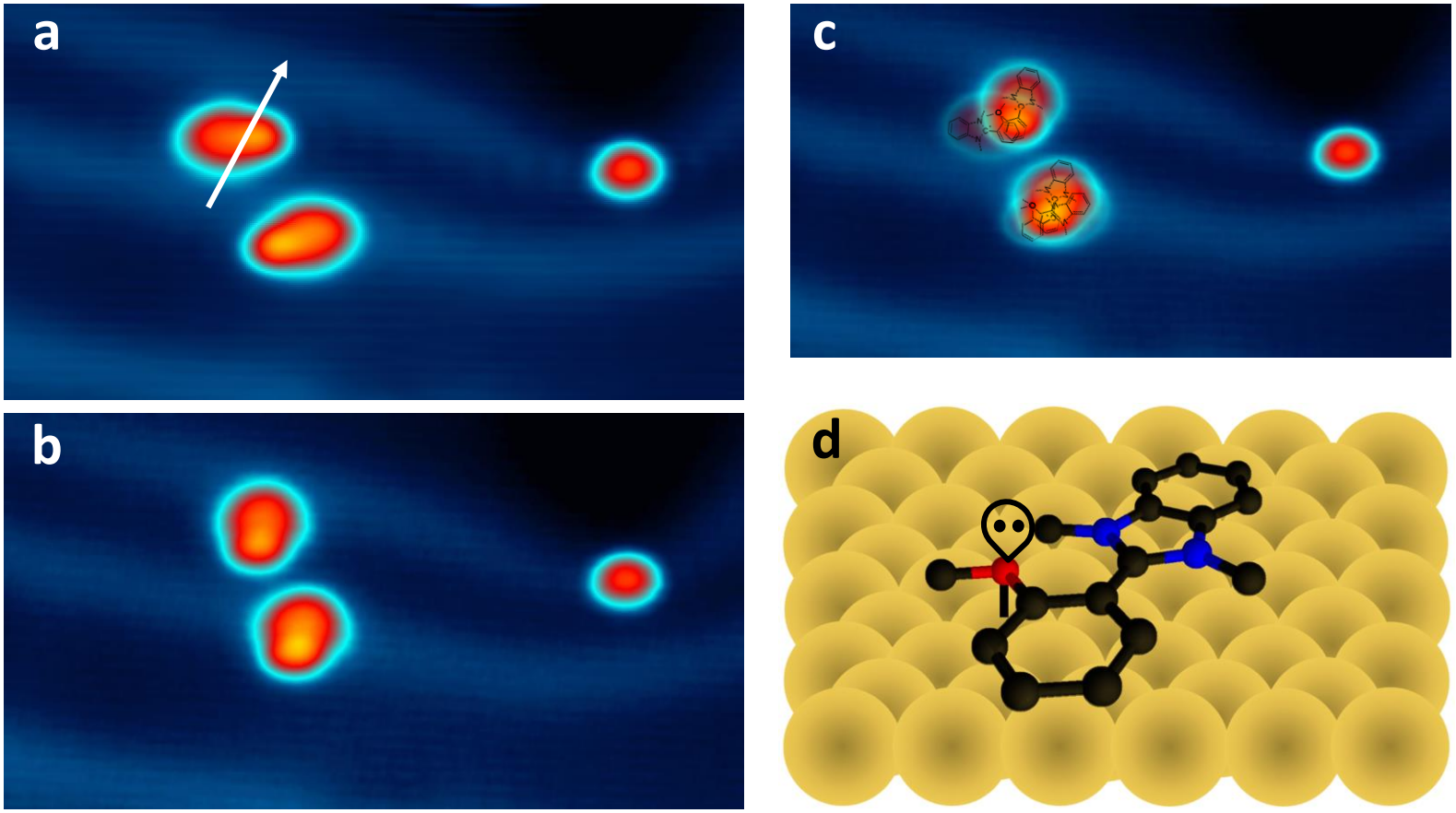


Figure 2. (a) Close-up image of two molecules on Au(111). By lateral manipulation (marked with the white arrow, parameters: I = 5.0 nA; V = 0.01 V) the molecules rotate around one point. The rotation can be clearly seen in (b). Figure (c) is an overlay of (a) and (b) pointing out the anchoring point. Figure (d) is showing the sketch of the anchored molecule.

Vertical manipulation of DMBI on Au(111)

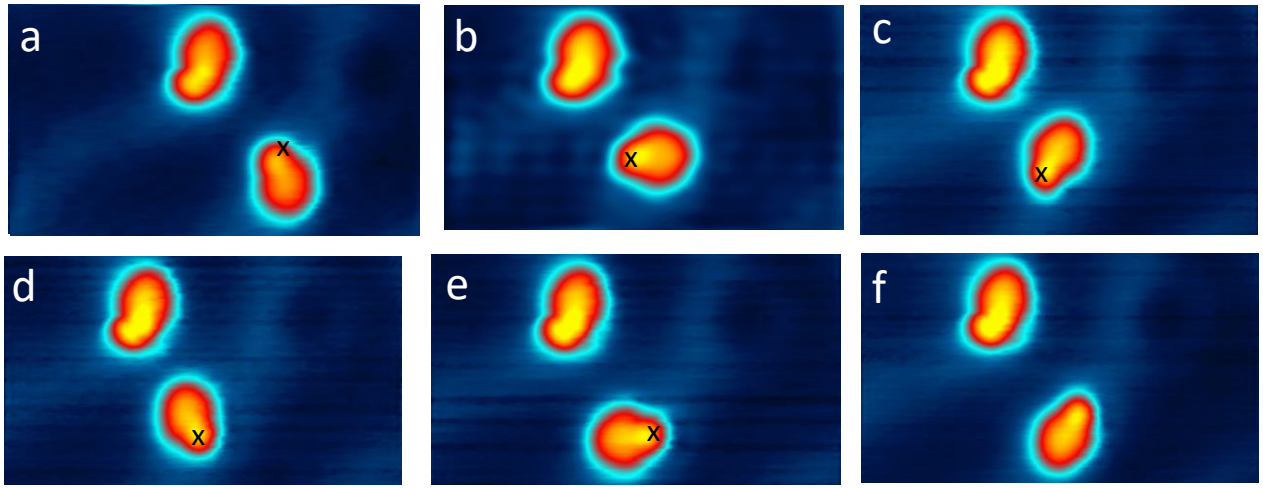


Figure . (a) – (f) Close-up images of two DMBI molecules. It was possible to rotate step by step the molecule via voltage pulses at the position marked with the black cross. (Manipulation parameters: $\boldsymbol{V_{bias}} = 0.7$ V and $\boldsymbol{I} = 0.1$ nA up to 0.5 nA; Image size: 8 nm x 4.5 nm; Image conditions: $\boldsymbol{V_{bias}} = 0.5$ V and $\boldsymbol{I} = 80$ pA).

DMBI as a gear on Au(111)

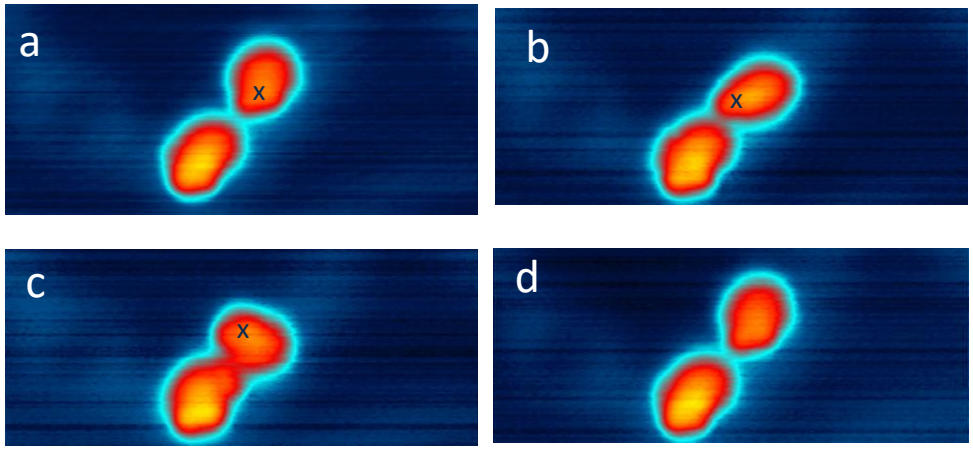


Figure . (a) – (d) In this series the upper molecule was rotated by voltage pulses(position marked with black cross) to induce also a rotation in the second molecule. As seen in (d) the lower molecule did not rotated, but the other molecule flipped back into its initial position. (Manipulation parameters: $\boldsymbol{V_{bias}} = 2.0$ V and $\boldsymbol{I} = 0.1$ nA up to 0.5 nA; Image size: 10 nm x 4.4 nm; Image conditions: $\boldsymbol{V_{bias}} = 0.5$ V and $\boldsymbol{I} =$ 30 pA).

DMBI on Au(111)

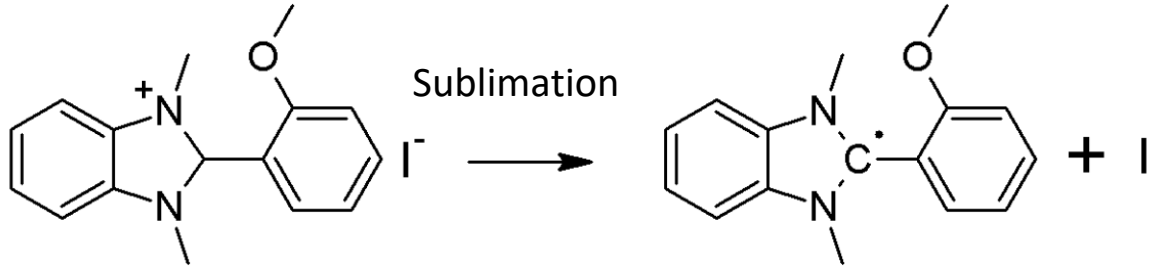


Figure. Formation of the radical o-MeO-DMBI compound by evaporation

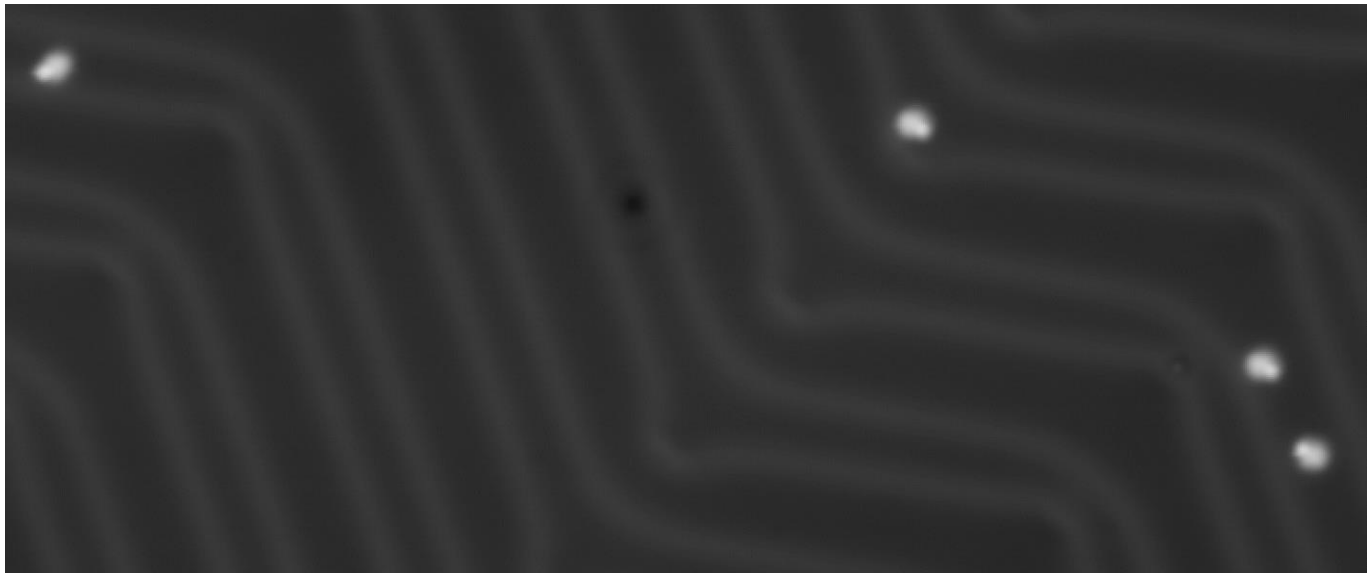
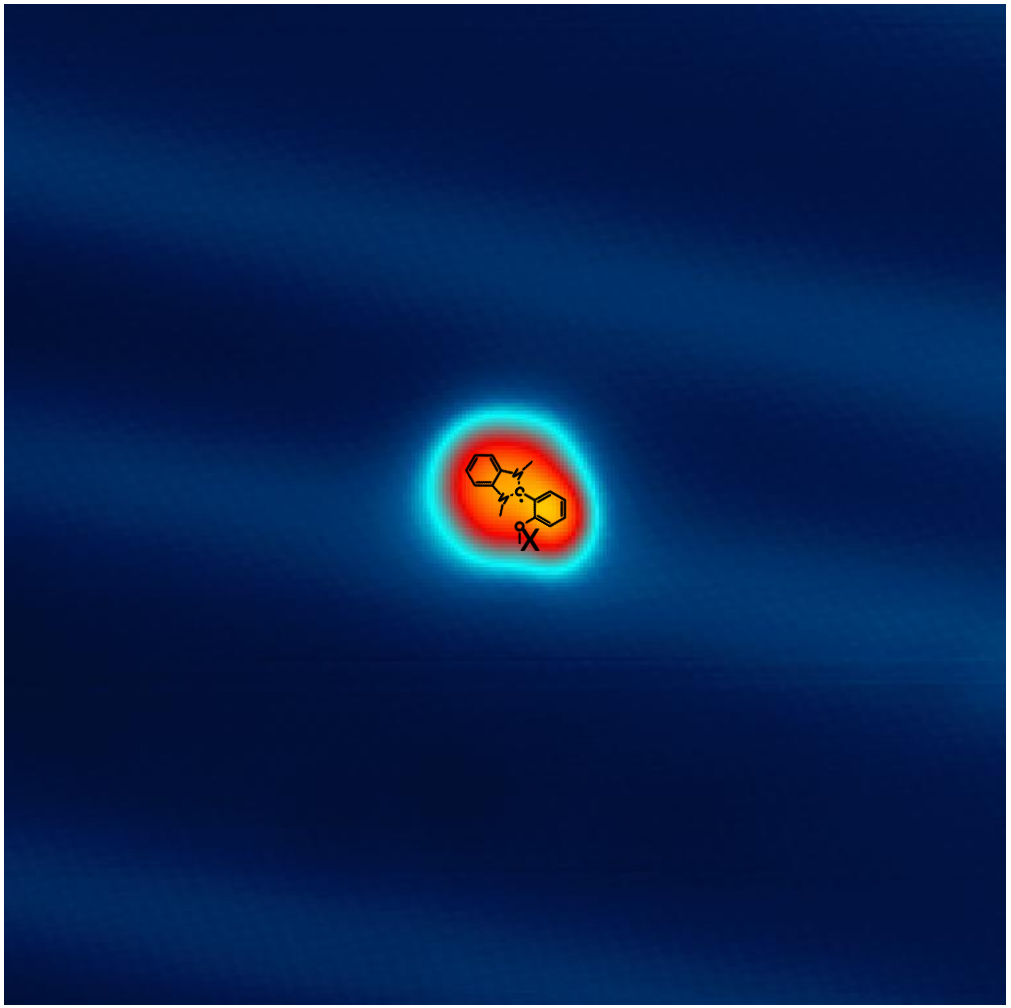


Figure. Coverage actual preparation (0.2 V; 100 pA; 60 nm x 25 nm)

DMBI on Au(111) – Rotation of an S-enantiomer

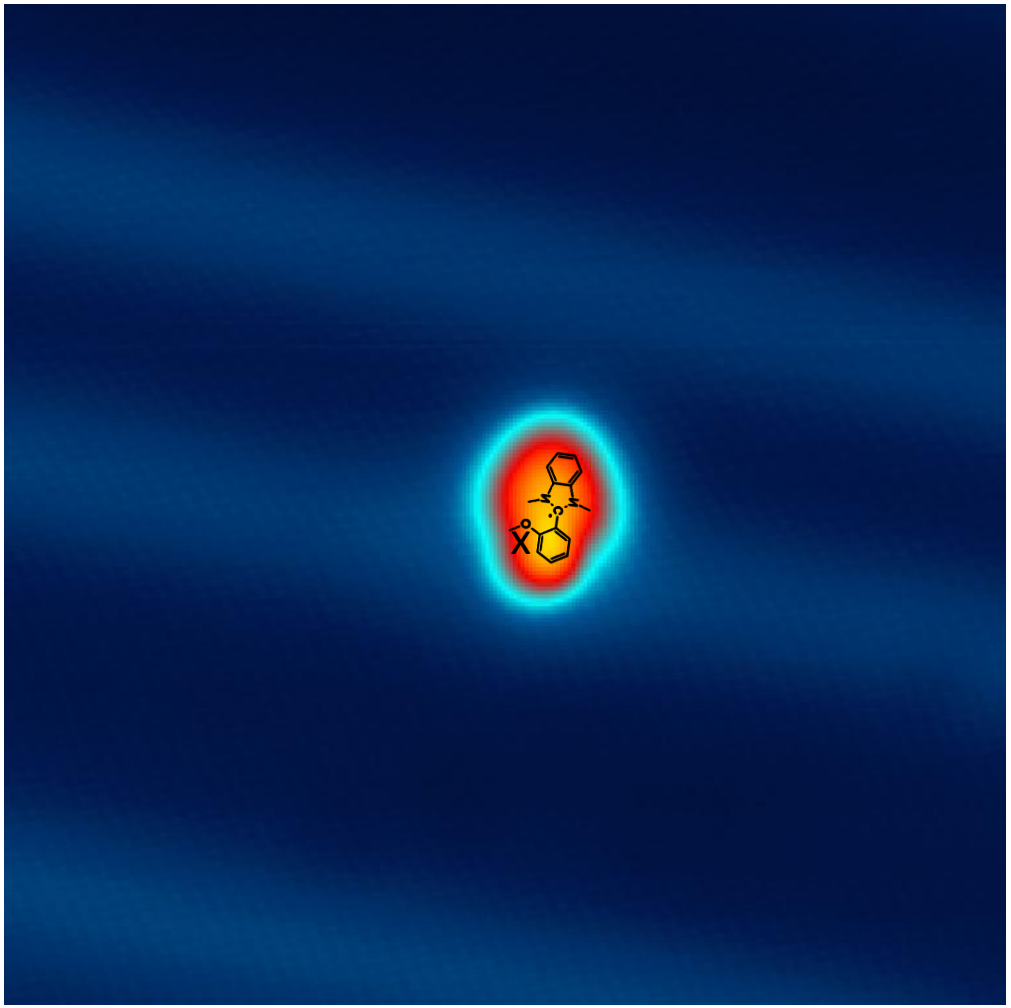


Clockwise rotation:
(Parameters:
bias 1.0 V; current: 500 pA;
Closed FB-loop)

-cross marks the voltage pulse position

Image: (0.2 V; 100 pA;
10 nm x 10 nm)

DMBI on Au(111) – Rotation of an S-enantiomer



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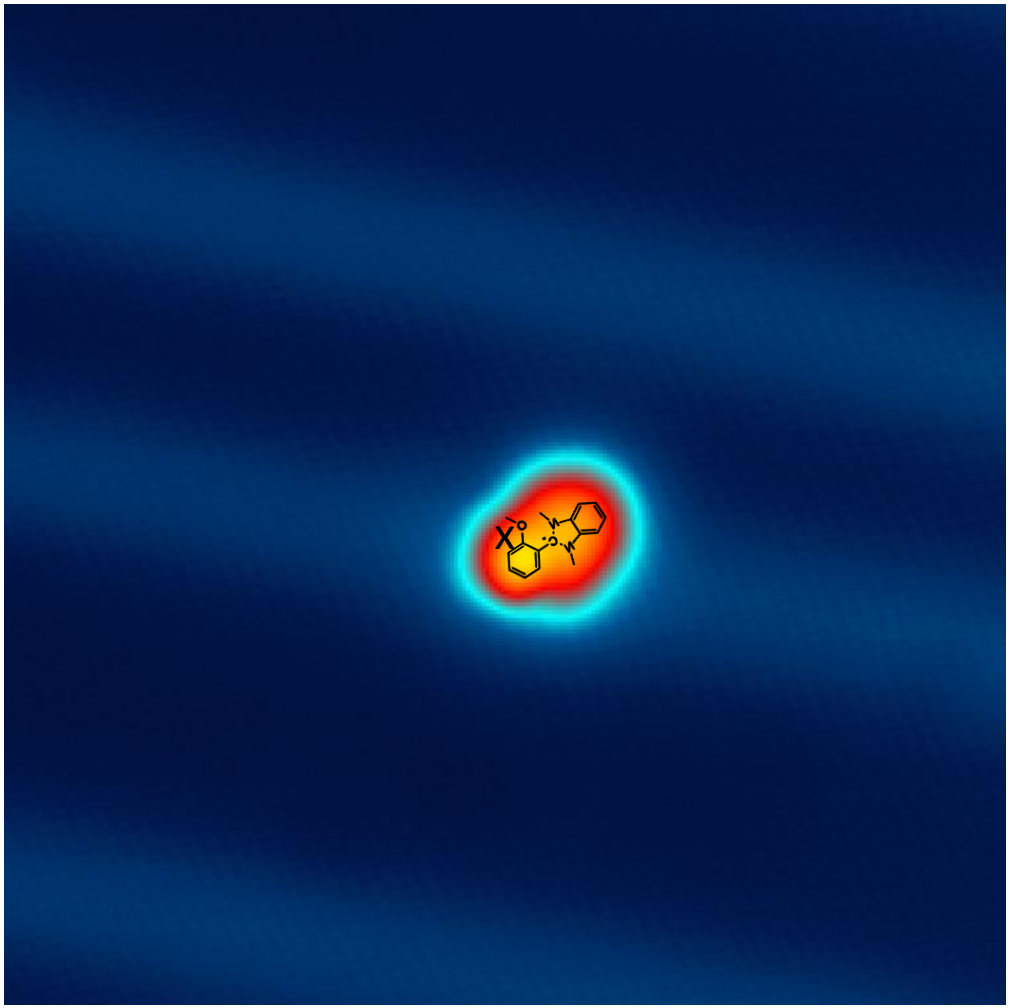

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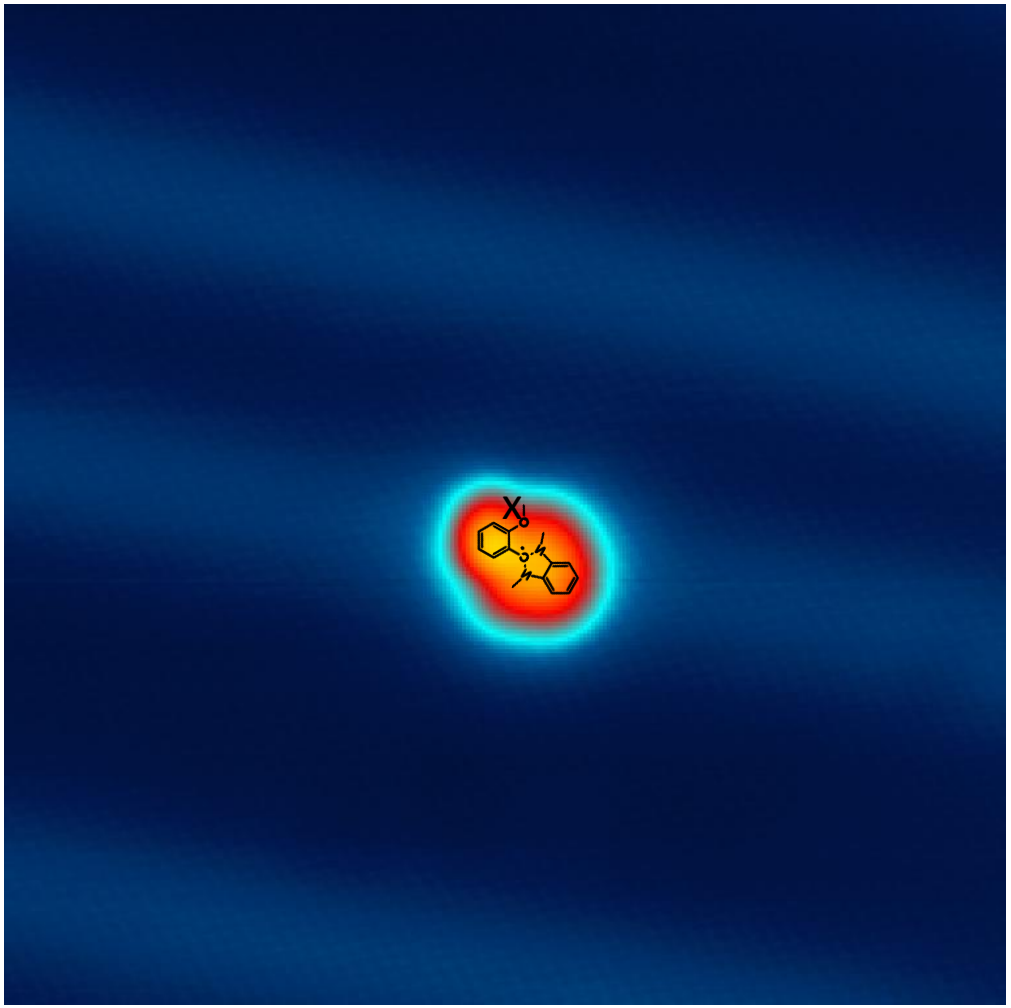

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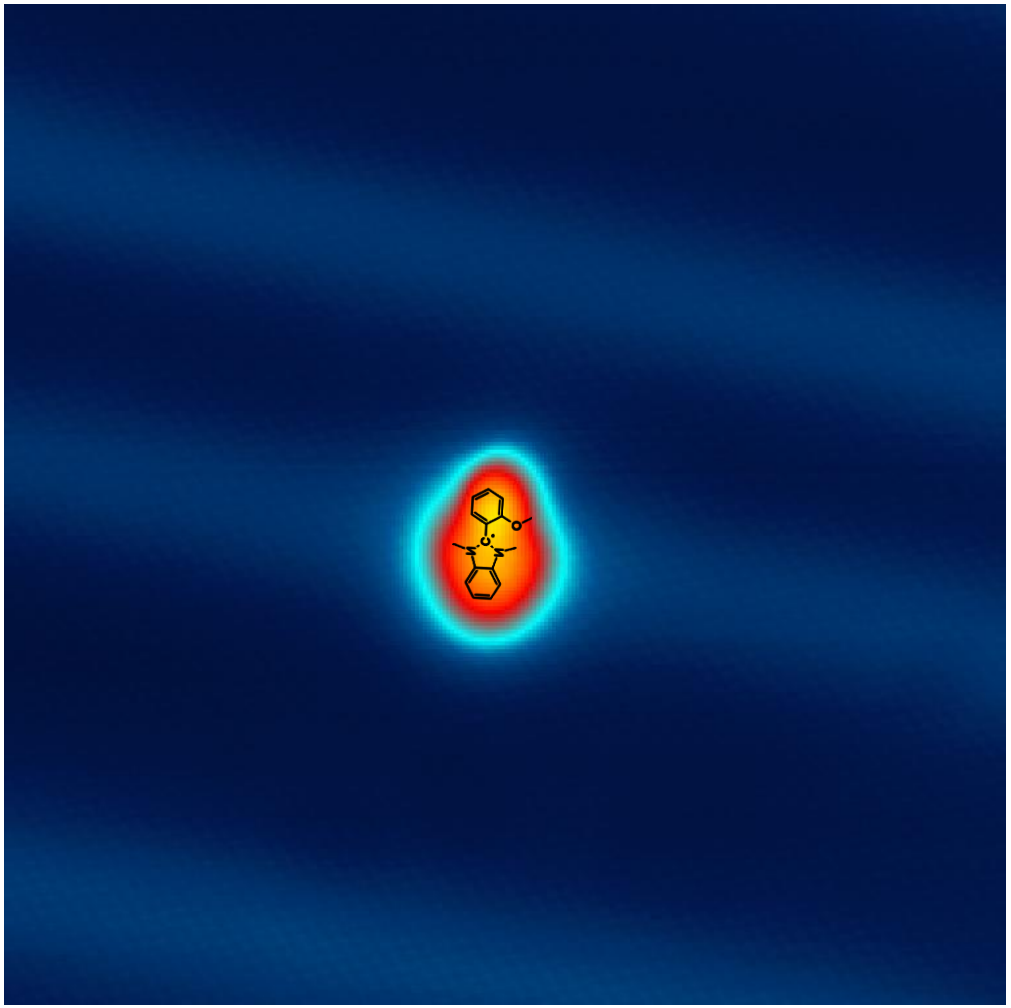

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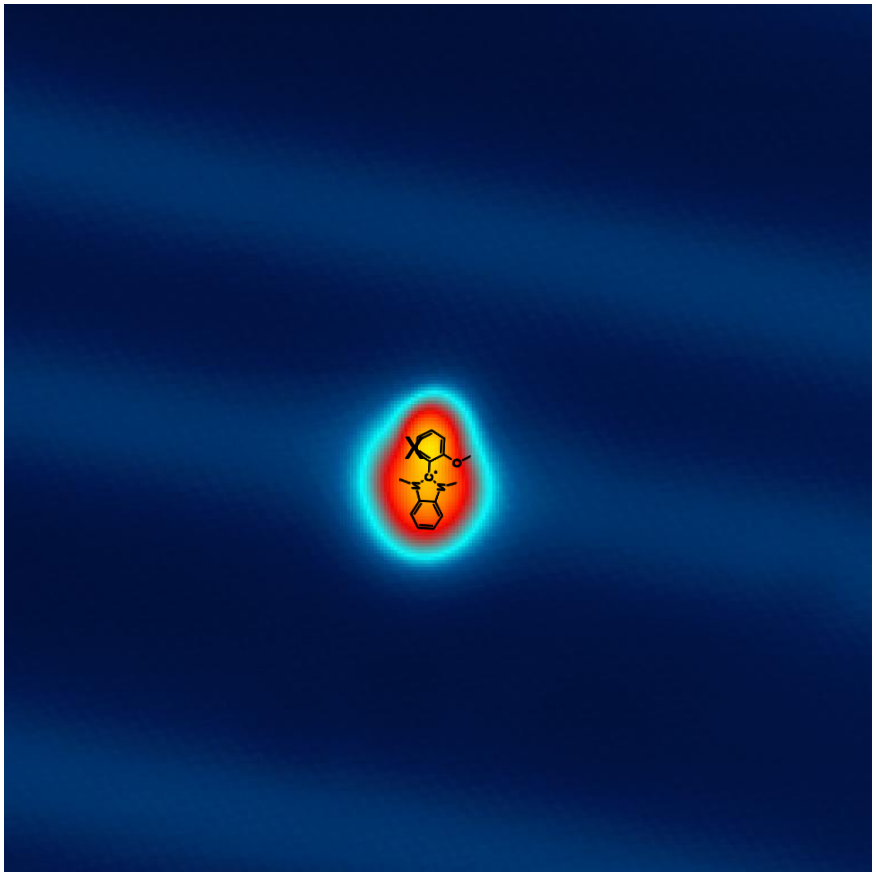

Counterclockwise rotation:
(Parameters:
bias -1.0 V; current: 500 pA;
Closed FB-loop)

-cross marks the voltage pulse position

Image: (0.2 V; 100 pA;
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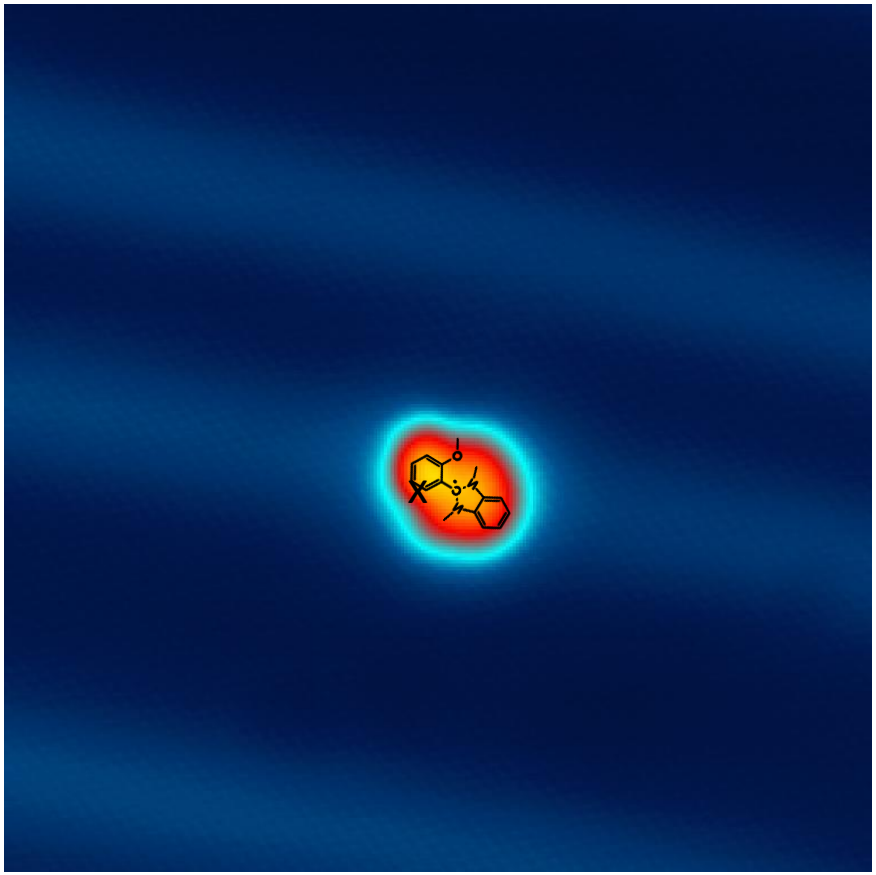
DMBI on Au(111) – Rotation of an S-enantiomer



Counterclockwise rotation:
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Closed FB-loop)

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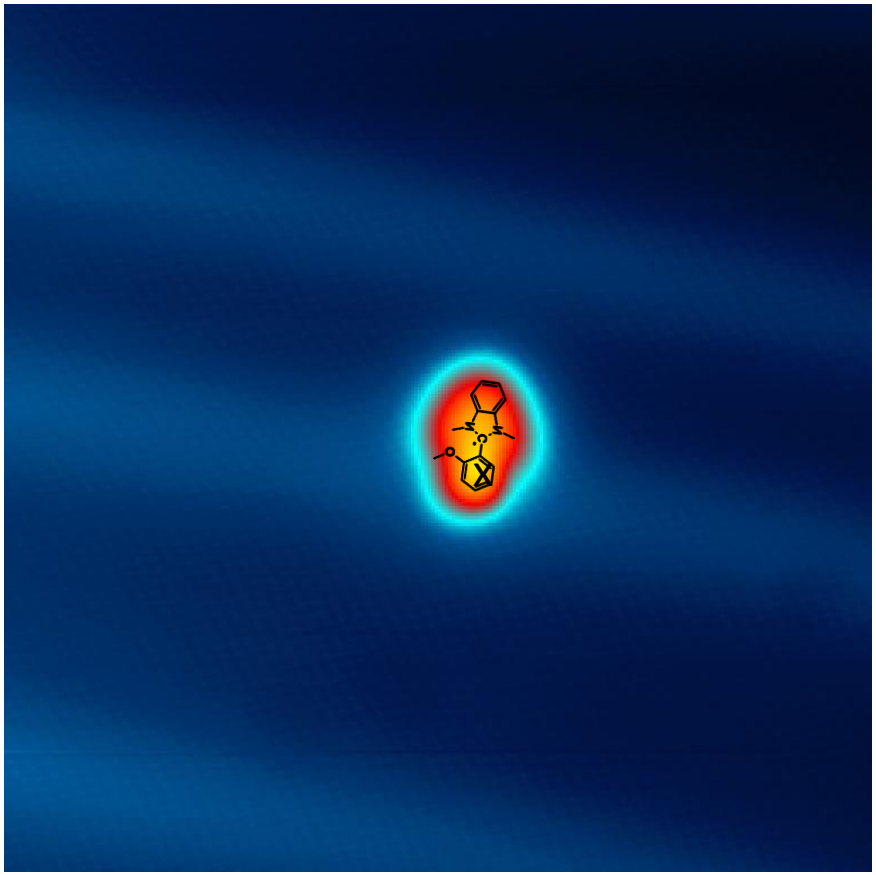
Image: (0.2 V; 100 pA;
10 nm x 10 nm)

DMBI on Au(111) – Rotation of an S-enantiomer



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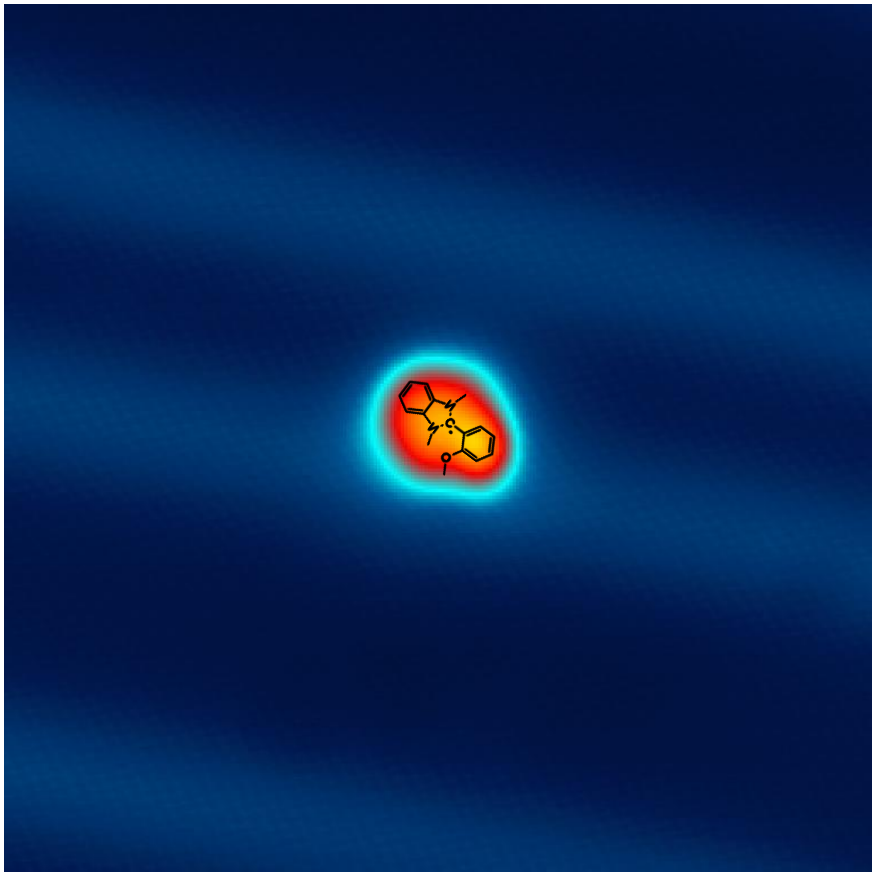

Counterclockwise rotation:
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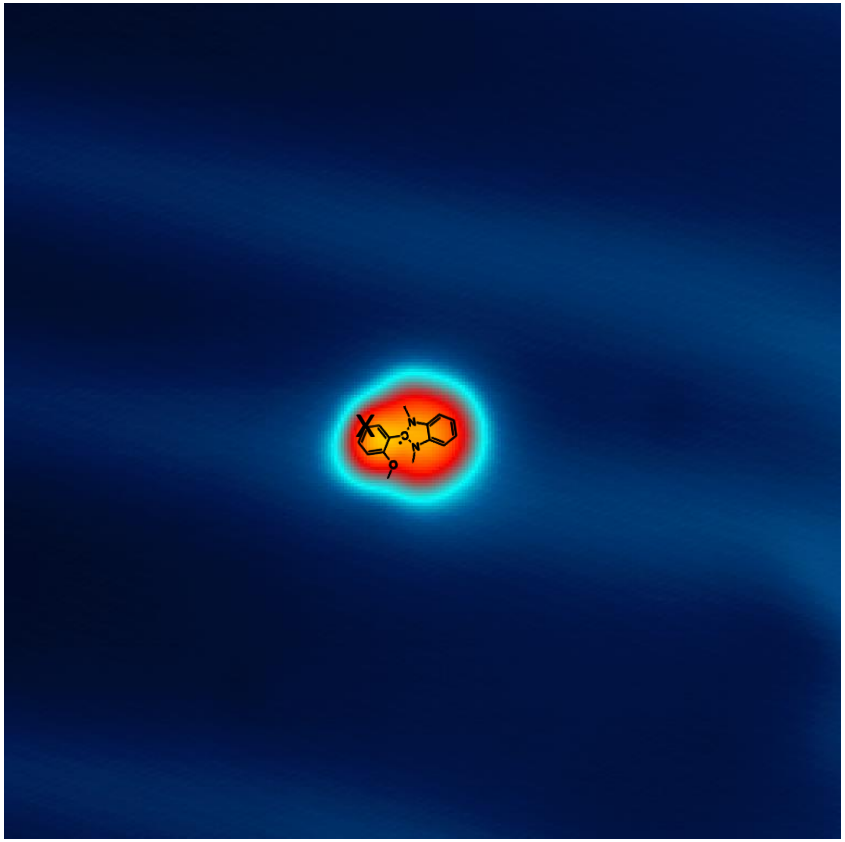
DMBI on Au(111) – Rotation of an R-enantiomer

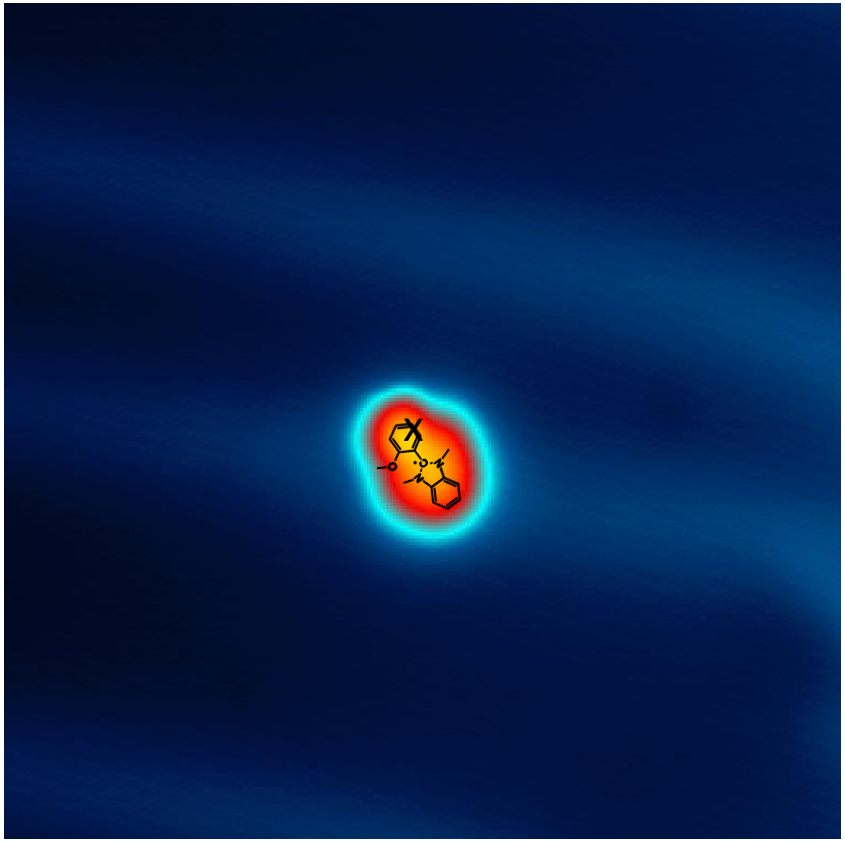


Clockwise rotation:
(Parameters:
bias - 0.7 V; current: 500 pA;
Closed FB-loop)

-cross marks the voltage pulse position

Image: (0.2 V; 100 pA;
10 nm x 10 nm)

DMBI on Au(111) – Rotation of an R-enantiomer



Clockwise rotation:
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Closed FB-loop)

-cross marks the voltage pulse position

Image: (0.2 V; 100 pA;
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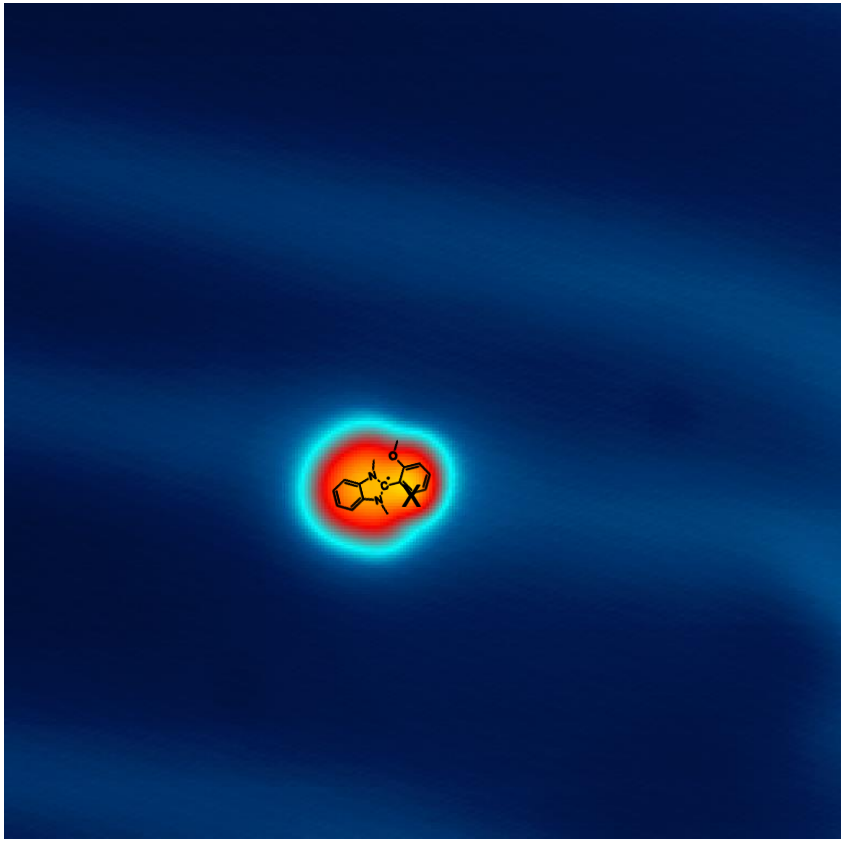
DMBI on Au(111) – Rotation of an R-enantiomer



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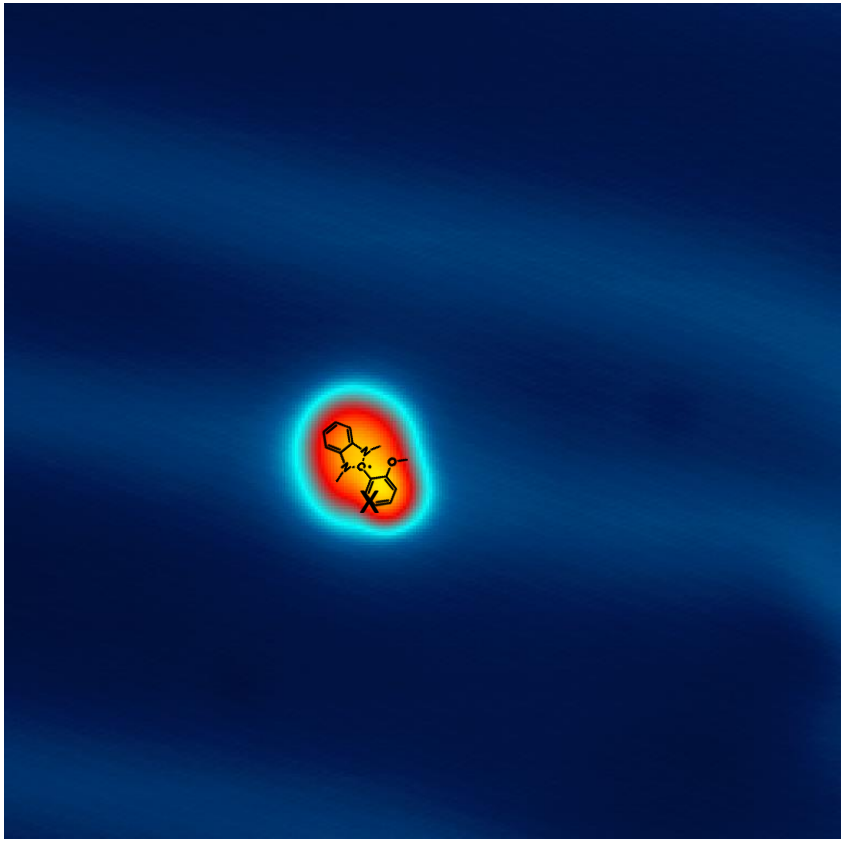

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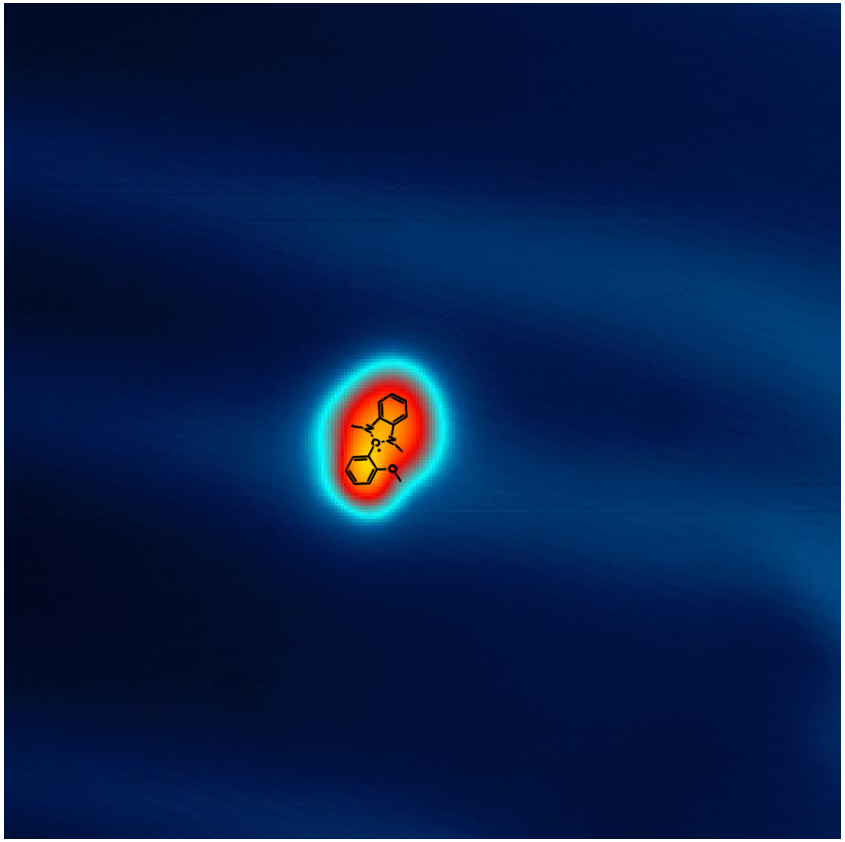

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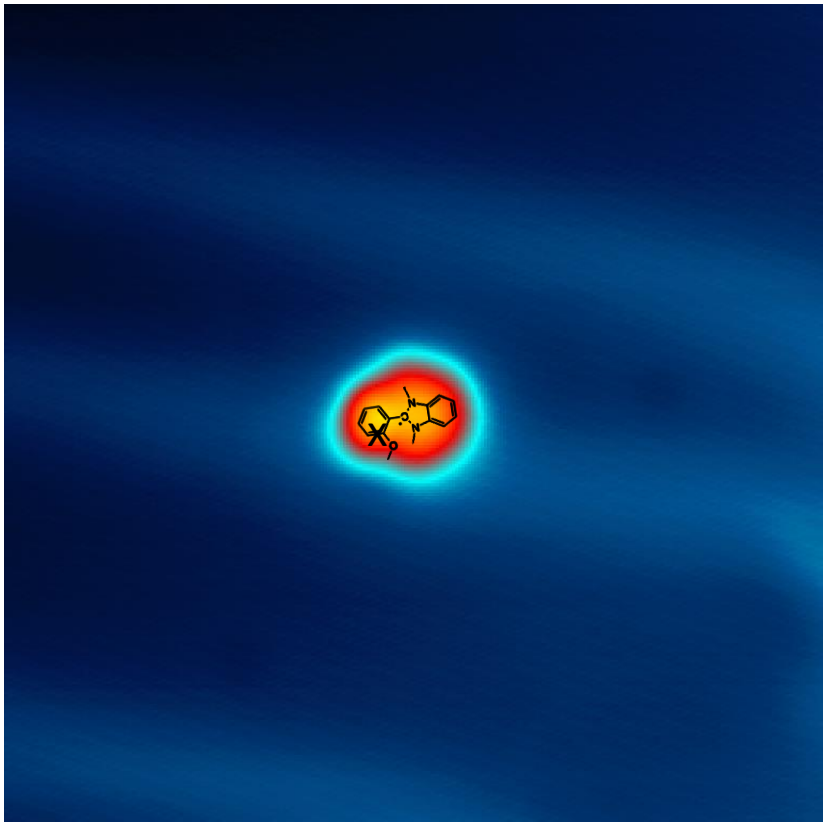

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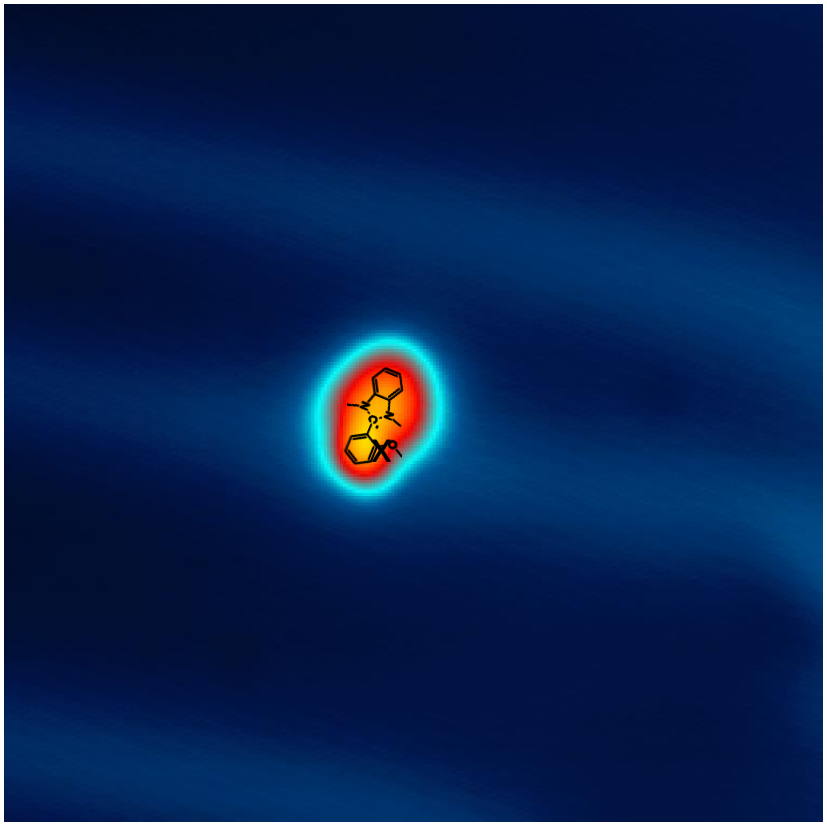

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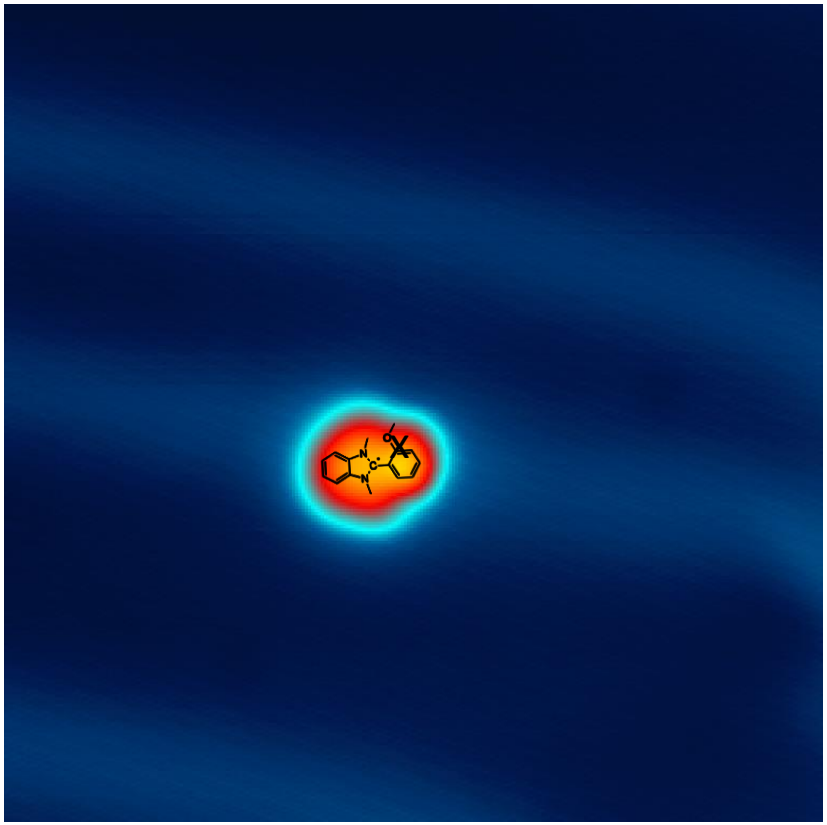

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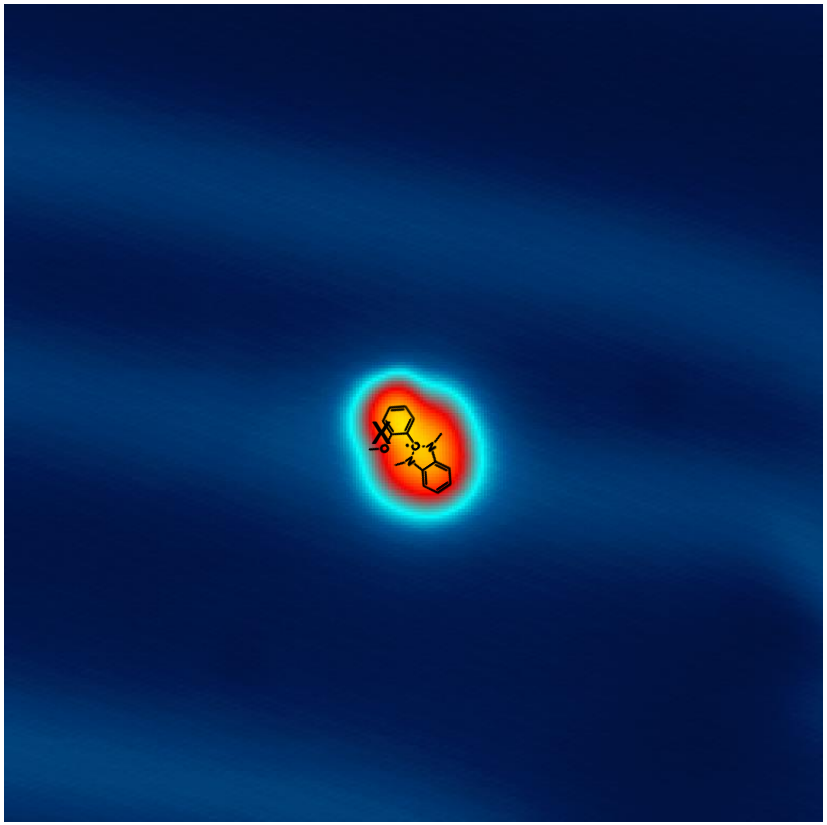

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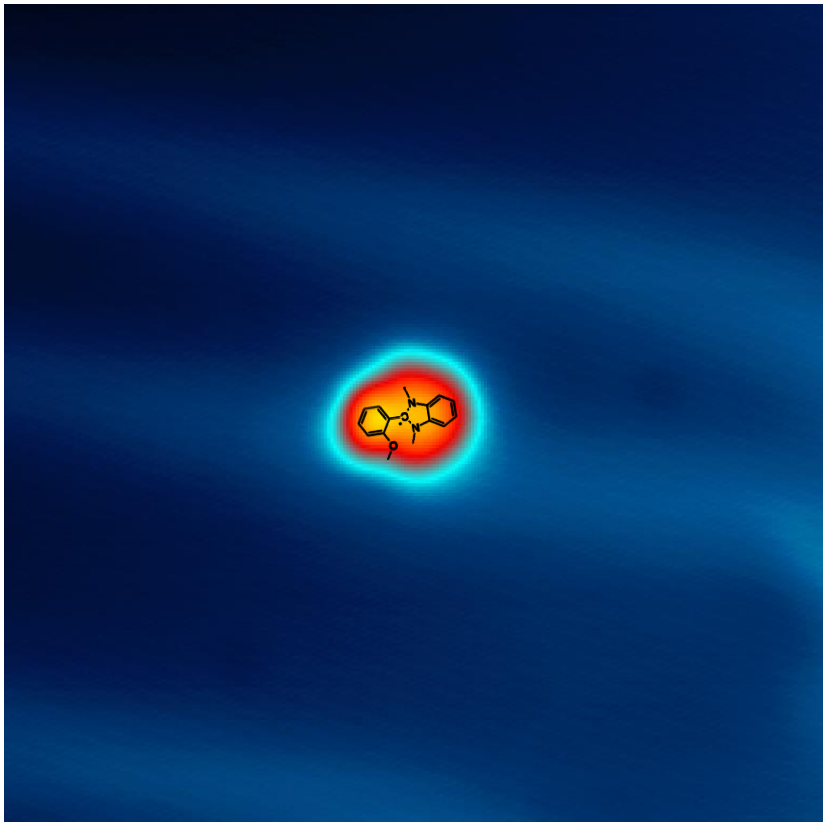

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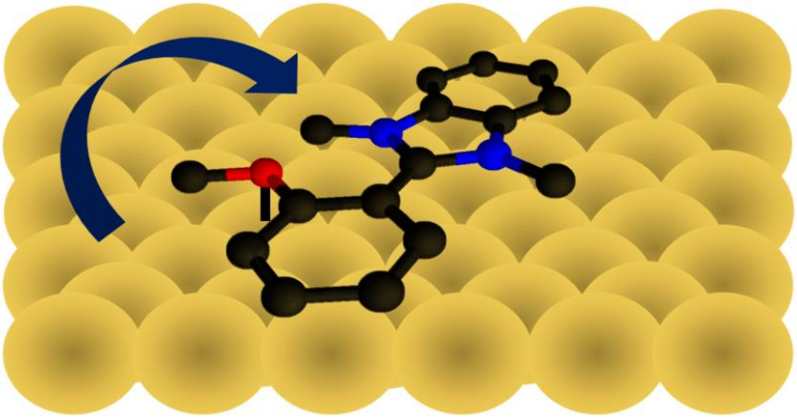
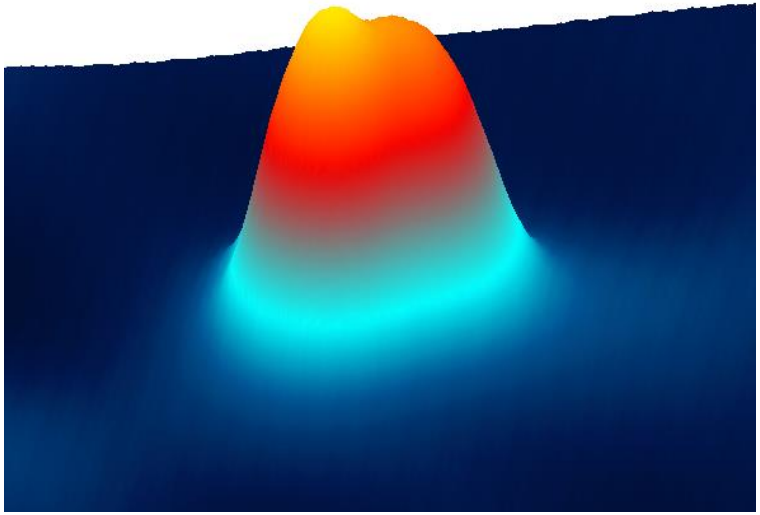
DMBI on Au(111) – General findings

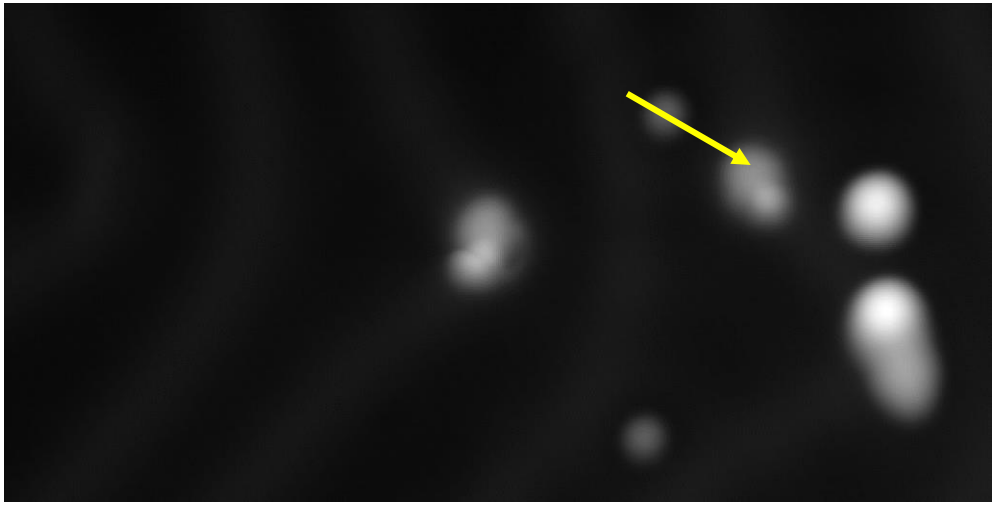


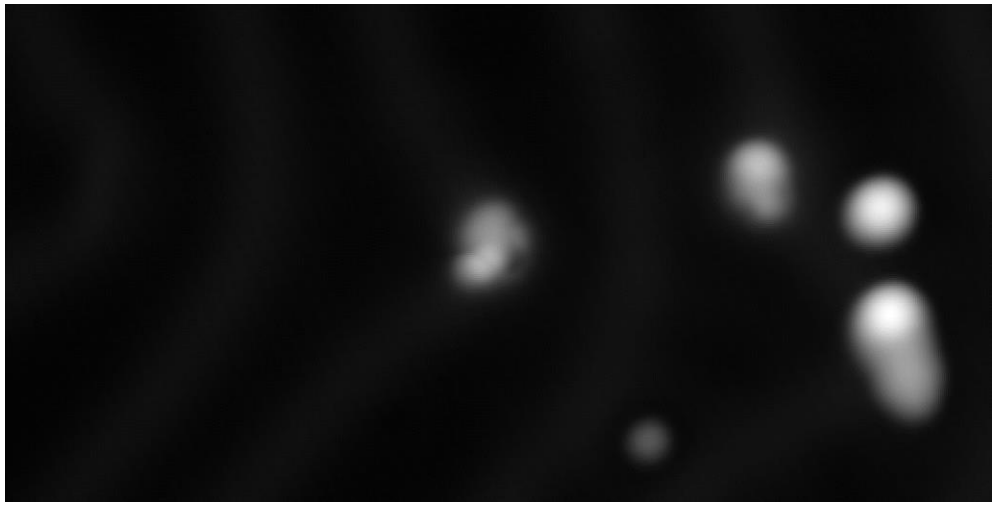
-retracting by 6 Å and applying ± 3 V did not lead to any rotation (not purely field effect)



-first events seen at ± 0.3 V

DMBI on Au(111) – Attaching a single Au-atom





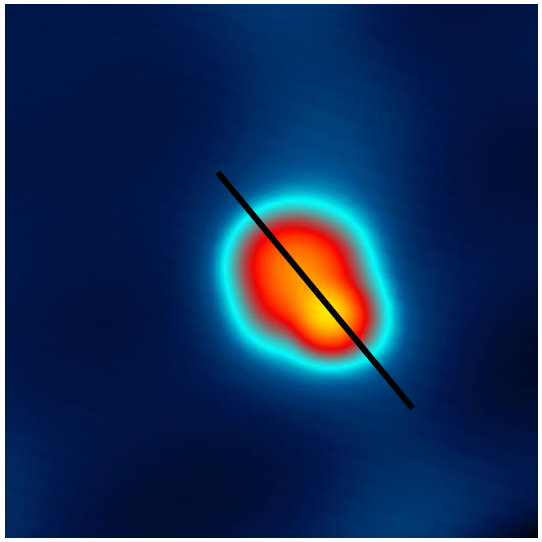
Au-atom production:
normal tip form procedure (tip approach 0.6 – 0.8 nm)

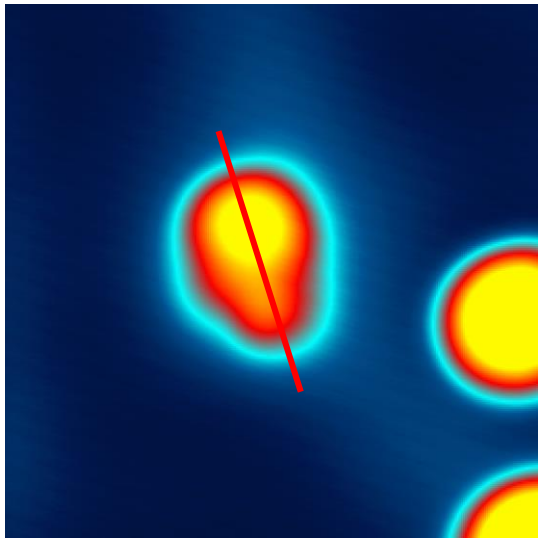
Au-atom manipulation:
-starting from 8 nA and 10 mV going up to 12 nA (for I>10 nA; preamplifier gain from 10^9 to 10^8)

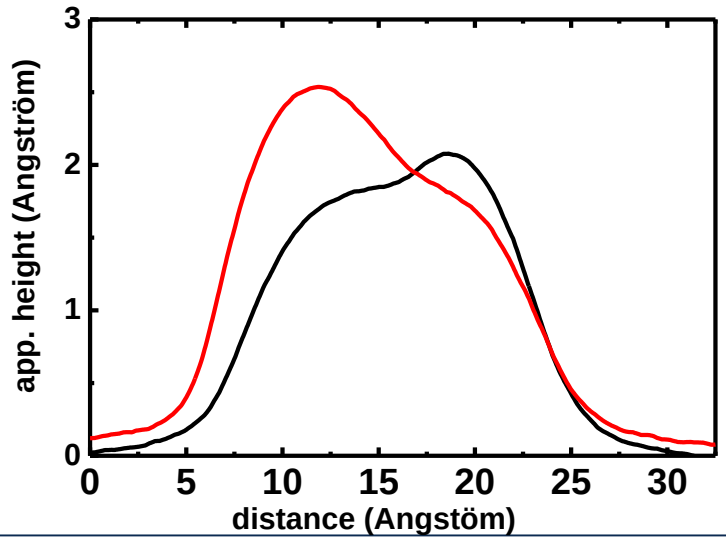
-able to attach Au-atoms to organic molecules

Image: (0.2 V; 100 pA;
20 nm x 10 nm)

DMBI on Au(111) – Attaching a single Au-atom







-comparison molecule without Au and with Au-atom

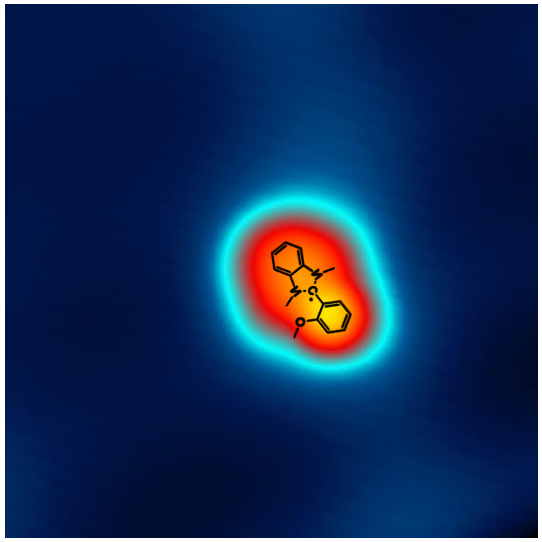
-after attaching Au-atom rotation not possible

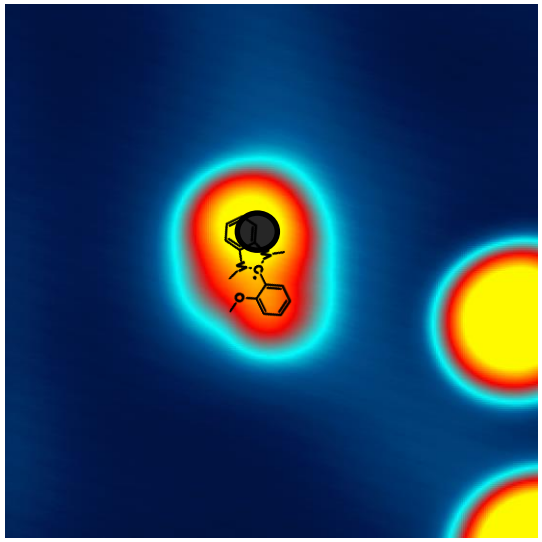
-voltage pulses up to ±2.5 V (500 pA)

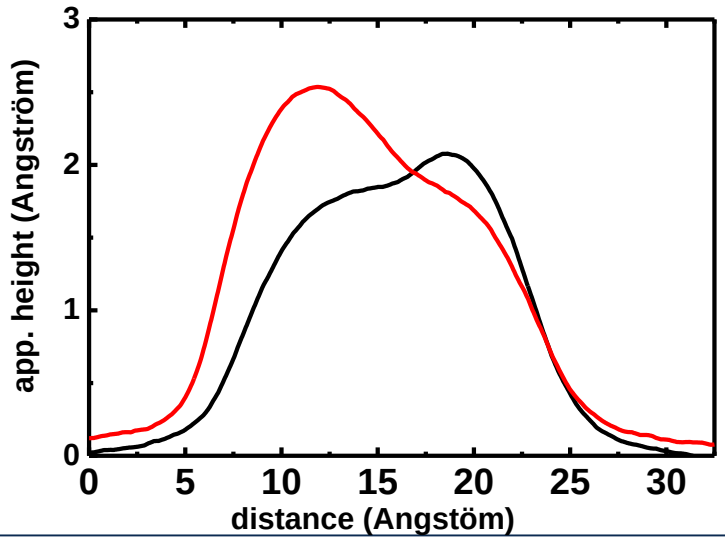
-at 3.0 V destroy the molecule

Image: (0.2 V; 100 pA; 5 nm x 5 nm)

DMBI on Au(111) – Attaching a single Au-atom







-comparison molecule without Au and with Au-atom

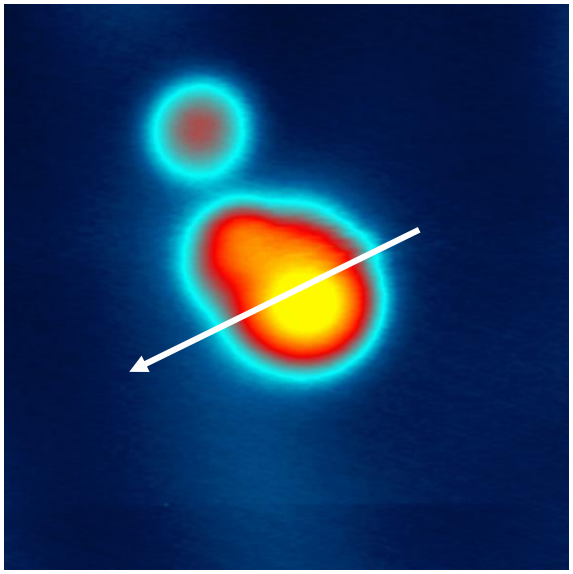
-after attaching Au-atom rotation not possible

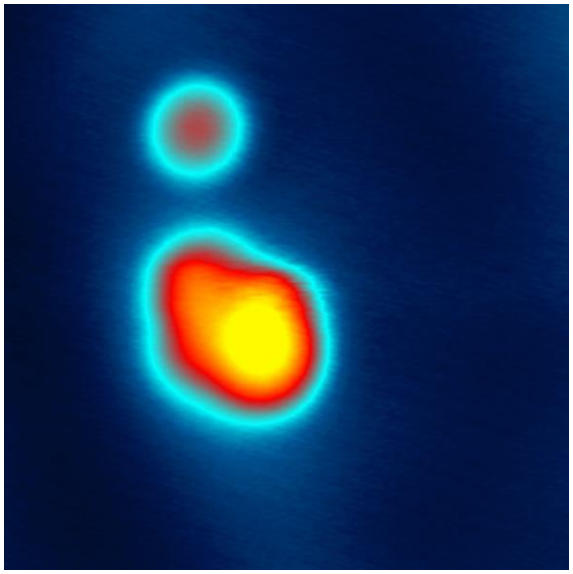
-voltage pulses up to ±2.5 V (500 pA)

-at 3.0 V destroy the molecule

Image: (0.2 V; 100 pA; 5 nm x 5 nm)

DMBI on Au(111) – Attaching a single Au-atom





Images: (0.2 V; 100 pA; 5 nm x 5 nm); Manipulation parameter: (10 mV; 4 nA)

- lateral manipulation of molecules with attached Au-atom

-rotation of the Au-molecule complex not possible