A Planar Scanning Probe Microscope

Supporting Information
13 pages, 4 figures

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1 Measurement of the minimum achievable sensor-sample distance

**Figure S1**: Measurement of the minimum achievable sensor-sample distance. 

a Measurement of the standoff distance $\Delta_{NV}$ of an NV center embedded a few nanometers beneath the sensor surface. Fluorescence (grey curve) is modulated upon approach of a silicon surface – at short distances because of the Purcell effect, at long distances due to standing waves in the excitation beam. We determine $\Delta_{NV}$ by fitting the standing waves (blue curve) and extrapolating the fit (green curve) to the node closest to contact, the position of which is $-\Delta_{NV}$. Contact is identified from a discontinuity in the fluorescence data and defined as $\Delta = 0$ nm. 

b Measurement of standoff distance for several NV centers (blue: approach, green: retract). Negative values arise from the uncertainty in fitting the data and identifying contact. Centers can approach samples to within less than 50 nm, comparable to the distance achieved in tip-based schemes.

We calibrate the minimum achievable sensor-sample distance in an independent measurement using NV centers (Fig. S1). Specifically, we measure the standoff distance $\Delta_{NV}$ of an NV center beneath the sensor surface to the sample. This generally differs from the minimal achieved air gap $\Delta$ at contact, because of residual tilt, and since the centers are embedded slightly beneath the diamond surface (nominal depth $10 - 20$ nm, 5 keV N$^+$ implant). We measure $\Delta_{NV}$ by an optical ruler of standing waves, which form as the laser employed for NV excitation reflects from the sample surface (Fig. S1a). We determine $\Delta_{NV}$ by fitting the standing wave modulation at large $\Delta$ and extrapolating the fit to the intensity minimum closest to sensor-sample contact. Since this point can be equated with the node forming at the sample surface, the position of this minimum yields an estimate of $\Delta_{NV}$. The additional modulation at shorter $\Delta$ is due to altered emission of the NV center rather than altered excitation. Two contributions are involved [1–3]: First, a geometric effect arising from self-interference of the NV dipole with its mirror image. Second, the Purcell effect alters the lifetime of the NV center, leading to an additional change in photoluminescence. These effects cannot be observed at larger $\Delta$ since the emission spectrum of the NV center is broad and oscillations rapidly dephase and average out. Performing this analysis on a series of NV centers yields estimates of
Measurement of the minimum achievable sensor-sample distance

$\Delta_{NV}$ between $-25$ nm and $+30$ nm, negative values arising from uncertainties of the fit and the identification of the contact point. This value is comparable to the standoff distance achieved in state-of-the-art experiments with tip-based schemes, typically around 50 nm [4].
2 Technical details of the setup

Figure S2: Optical setup. a Interference microscope for tilt control b polarisation microscope for distance control. In reality, both microscopes shared the same hardware.

We performed all experiments in a homebuilt confocal microscope, upgraded by the 5D-nanopositioner, as well as optics for interference reflection microscopy and polarisation microscopy (Figure S2). The microscope employs the infinity corrected immersion oil objective Olympus UPlanSApo 60x with a numerical aperture of 1.35. A camera of type UI-3860CP-M-GL Rev.2 by IDS Imaging Development Systems GmbH was used which has a Sony IMX290 CMOS monochrome sensor. The laser was a frequency-doubled Nd:YAG laser (\(\lambda = 532\) nm), the power used for illumination was 1 mW or less. For measurements on NV centers, a second laser (switched free-running diode, \(\lambda = 520\) nm) was used additionally in a confocal configuration. It was introduced to the beam path by a second beamsplitter cube.
3 Derivation of fit functions

The fit functions used in Fig. 2b and Fig. 3c of the main text are both based on the same formalism to describe the reflection behavior of a layer system, here constituted of diamond, air gap, and silicon substrate. First, the analytical derivation of the reflection coefficients is given. Second, the effect of analyzer and polarizer is included and the resulting camera intensity is derived. Finally, the expressions for the fit functions used in the main text are presented.

3.1 Reflection coefficients

The Fresnel equations describe the polarization and phase change upon reflection and transmission at a material interface. For multilayer systems, these reflexes coherently add up to the overall reflection property, which can exhibit Angstrom level sensitivity to the thickness of the layers in the stack (e.g. in an ellipsometer). In the Jones formalism, a plane wave incident on a layer system under some angle $\theta$ to the normal is expressed with a Jones vector $(E_p, E_s)_{in}$ that is written in the basis of p- and s-polarized light. They represent the parallel and perpendicular field component relative to the plane of incidence and $\hat{e}_p \times \hat{e}_s = \hat{e}_k$. Reflections at each layer interface add up coherently to form the overall reflected beam. This beam is described by a new Jones vector $(E_p, E_s)_{out}$ with different polarization and amplitude compared to the incoming beam. For isotropic materials, the reflection process can be described by a Jones matrix as

$$
\begin{pmatrix}
E_p \\
E_s
\end{pmatrix}_{out} = \begin{pmatrix}
r_p & 0 \\
0 & r_s
\end{pmatrix} \cdot \begin{pmatrix}
E_p \\
E_s
\end{pmatrix}_{in}.
$$

Thus, the p- and the s-component can be treated completely independent from each other to find the reflection coefficients $r_p$ and $r_s$. We use the transfer-matrix method to obtain an analytical expression of $r_p$ and $r_s$ for an arbitrary stratified medium composed of homogeneous layers and in the absence of depolarization effects. The interfaces are assumed to be ideally flat and parallel and the incoming light is a plane wave. This method was introduced by Abelès [5] and the derivation results given here basically follow Born & Wolf [6, p. 54–64].

For a given incoming electromagnetic wave and a given layer system, there is a well-defined field distribution in the entire system. This field distribution is the only solution to the Maxwell equations for given boundary conditions. We examine the general situation illustrated in figure S3: a plane wave with wavelength $\lambda_0 = \lambda/n_0$, where $\lambda$ is the vacuum wavelength, is assumed to be incident on a stratified material under an angle $\theta$. The ambient medium has to be a dielectric with a real-valued refractive index $n_0$ (non-absorbing). The different layers are labeled by the index $k$ with respective thickness $S_k$.
$d_k$ and refractive index $n_k$. They can have a non-zero conductivity and be absorbing with complex refractive index. They can also be para- or diamagnetic. Only situations where the material equations cannot be written with the simple linear scalars $\epsilon$ and $\mu$, as e.g. ferromagnets, are not covered by this theory. The entire layer system is sitting atop a substrate with complex refractive index $n_s$. We first look at the electric field $\vec{E}_s$, of the s-polarized component of the incident light $\vec{E}_{\text{in}} = (E_{s,\text{in}}, E_{p,\text{in}})$ right above the first interface. The overall electric field at this point is the sum of the incoming and outgoing electric field $\vec{E}_{s,\text{in}} + \vec{E}_{s,\text{out}}$ while the magnetic field can be found from $\vec{H} = \sqrt{\epsilon/\mu} (\hat{e}_{\text{in}} \times \vec{E}_{s,\text{in}} + \hat{e}_{\text{out}} \times \vec{E}_{s,\text{out}})$. Using Maxwell’s equations, these boundary conditions can be applied to solve the differential equations of the medium self-consistently. A $2 \times 2$-matrix $M$ can be found, which, through simple multiplication with a vector containing the boundary conditions, gives the fields at any point in the medium. This formalism is applied to find an expression for the transmitted field $\vec{E}_{s,\text{trans}}$ on the substrate side of the last interface. Using this, the equations can be solved for the desired reflection coefficient $r_s = E_{s,\text{in}}/E_{s,\text{out}}$ of the s-polarized light, which is found to be

$$r_s = \frac{(M_{s,11} + p_s M_{s,12}) p_0 - (M_{s,21} + p_s M_{s,22})}{(M_{s,11} + p_s M_{s,12}) p_0 + (M_{s,21} + p_s M_{s,22})}.$$  

(3.2)

Here,

$$p_0 = \frac{1}{\mu_0} \sqrt{n_0^2 - n_0^2 \sin(\theta)^2},$$

$$p_s = \frac{1}{\mu_s} \sqrt{n_s^2 - n_s^2 \sin(\theta)^2},$$

(3.3)

and the matrix elements $M_{s,ij}$ are found from the characteristic matrix of the stratified

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**Figure S3:** A plane wave is incident on a stratified layer of refractive indices $n_k$ and thicknesses $d_k$ sitting on a substrate with $n_s$. 

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3 Derivation of fit functions
\textbf{3 Derivation of fit functions}

\[ M_s = \begin{pmatrix} M_{s,11} & M_{s,12} \\ M_{s,21} & M_{s,22} \end{pmatrix} = M_{s,1} \cdot M_{s,2} \cdot M_{s,3} \cdot \ldots \ , \]  \hspace{1cm} (3.4)

where each matrix \( M_{s,k} \) is the characteristic matrix of one layer \( k \). They are found from

\[ M_{s,k} = \begin{pmatrix} \cos(\rho_k) & -i p_k \sin(\rho_k) \\ -i p_k \sin(\rho_k) & \cos(\rho_k) \end{pmatrix} , \]  \hspace{1cm} (3.5)

with

\[ \rho_k = \frac{2\pi}{\lambda} d_k \sqrt{n_k^2 - n_0^2 \sin(\theta)^2} \]  \hspace{1cm} (3.6)

and

\[ p_k = \frac{1}{\mu_k} \sqrt{n_k^2 - n_0^2 \sin(\theta)^2} \]  \hspace{1cm} (3.7)

To find the reflection coefficient \( r_p = E_{p,\text{in}}/E_{p,\text{out}} \) of the p-polarized component of the incident light, one can make use of a fundamental symmetry in the Maxwell’s equations for the present case: They are invariant under simultaneous exchange of \( \vec{E} \) with \( \vec{H} \) and \( \epsilon \) with \( -\mu \). This way, the magnetic field of the reflected p-wave can be found from the incident magnetic field in complete analogy to the previous derivation. Then, one can find the electric field behavior from the magnetic field. It shall be noted that two inverse coordinate transformations are required here as the p-s-coordinate system is dependent on the angle of incidence whereas the material stack is independent. But finally, the relations for the p-polarized light are almost of the same form as the ones for the s-polarized light. Substituting as follows in \( r_s \) in equation 3.2 gives \( r_p \) instead:

\[ p_0 \rightarrow q_0 = \frac{\mu_0}{n_0^2} \sqrt{n_k^2 - n_0^2 \sin(\theta)^2} \]

\[ p_s \rightarrow q_s = \frac{\mu_s}{n_s^2} \sqrt{n_s^2 - n_0^2 \sin(\theta)^2} \]

\[ p_k \rightarrow q_k = \frac{\mu_k}{n_k^2} \sqrt{n_k^2 - n_0^2 \sin(\theta)^2} \]  \hspace{1cm} (3.8)

Combining equations 3.2, 3.8, and 3.1 for a given stratified medium \( n_k, d_k \) one now obtains the angle \( \theta \) dependent reflection Jones matrix as

\[ R = \begin{pmatrix} r_p & 0 \\ 0 & r_s \end{pmatrix} . \]  \hspace{1cm} (3.9)

\textbf{3.2 Camera intensity}

Having an analytical expression for the reflection behavior, we can now model the full optical setup and predict the camera intensity for the different operation modes -
interference reflection microscopy for tilt alignment and total internal reflection microscopy for distance control. Referring to Fig. 1 and Fig. 3a of the main text, and Fig. S2 of the Supporting Information, we introduce the following system parameters:

- The relative angle \( \alpha \) between polarizer and analyzer. In our case, the polarizing beamsplitter cube acts as a polarizer and analyzer at the same time and causes \( \alpha = 90^\circ \). This is used for total internal reflection microscopy in Fig. 3. For the experiments utilizing interference reflection microscopy in Fig. 2 we put a linear polarizer with \( 45^\circ \) orientation relative the polarizing beam-splitter cube in front of the objective. This effectively gives us a setting with \( \alpha = 0^\circ \).

- The angle of incidence \( \theta \) of the light reaching the diamond to air interface relative to the normal as introduced above.

- The polarization angle \( \gamma \) of the light incident on the diamond to air interface. Due to the polarizer, this incident light is always linearly polarized. An angle of \( \gamma = 0^\circ \) means pure \( p \)-polarized light, an angle of \( \gamma = 90^\circ \) represents pure \( s \)-polarization. If the light in the back-focal plane in Fig. 3a was polarized in the plane of the drawing, then it would be incident on the sensor and sample interface with \( \gamma = 0^\circ \).

- The air gap \( \Delta \) between sample and probe as used in the main text.

The values of \( \theta \) and \( \gamma \) can conveniently be adjusted by focusing the laser in Fig. 3a to different spots in the back-focal plane of the objective. Therefore, the lens on the left is mounted on a mechanical stage with two axes that allow to move the focal spot to every point in the back-focal plane. This point can be quantitatively read out from the spot position on an alignment grid which is placed below the open port of the polarizing beamsplitter cube with the same distance to it as the back-focal plane has. If the lens is centered on the optical axis, the focal spot of the laser will lie on the optical axis too. This situation yields a perpendicular incidence with \( \theta = 0^\circ \). For a focus further away from the optical axis, the collimated light beam will be incident on the sensor and sample interface at a larger angle \( \theta \). This means, if the point of focus in the back-focal plane is expressed in polar coordinates with the optical axis at the center, then the radius determines \( \theta \). The polar angle of these coordinates, on the other hand, happens to equal the polarization angle \( \gamma \). This relation arises as follows: The polarization of the incident light in the back-focal plane is fixed by the polarizing beamsplitter cube. The objective will maintain this polarization in the lab frame but change the direction of \( \vec{k} \). The \( p \)- and \( s \)-coordinate system on the other hand is defined relative to \( \vec{k} \) and thus depends on its direction. As a result, the position of the focus in the back-focal plane determines the change of \( \vec{k} \) which, in return, determines the orientation of \( \hat{e}_p \) and \( \hat{e}_s \). Therefore, we must apply a coordinate transform when we switch back and forth from the \( p \)- and \( s \)-coordinate system to the lab frame. In the Jones formalism, this turns out to be
3 Derivation of fit functions

rotation $T$ by the polarization angle $\gamma$

$$T(\gamma) = \begin{pmatrix} \cos(\gamma) & \sin(\gamma) \\ -\sin(\gamma) & \cos(\gamma) \end{pmatrix}$$

(3.10)

Now, following the train of optical elements in Fig. 3a that a ray passes, the electric field at the camera is given by

$$\begin{pmatrix} E_x \\ E_y \end{pmatrix} = T(-\alpha) \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix} T(\alpha) \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} T_p(\theta, \Delta) & 0 \\ 0 & T_s(\theta, \Delta) \end{pmatrix} \begin{pmatrix} 1 \\ 0 \end{pmatrix}.$$  

(3.11)

The matrix for the sign inversion of the p-component arises from the altered direction of $\hat{k}$. It only affects the p-component, which can be intuitively understood when considering the limit of almost perpendicular incidence to a reflecting surface: Here the direction of $\hat{e}_p$ is inverted, while $\hat{e}_s$ stays the same. Finally now, the counts $C$ are proportional to the intensity

$$C \propto \left| \begin{pmatrix} E_x \\ E_y \end{pmatrix} \right|^2.$$  

(3.12)

3.3 Fit equations

Let us first consider the case of interference reflection microscopy (IRM), which is used for tilt alignment and the fit in Fig. 2b. Here, we choose polarizer and analyzer to be effectively parallel, thus $\alpha = 0^\circ$. Moreover, we intend to use a normal incidence and thus $\theta = 0^\circ$. The oscillation period of the fringes as well as the fit are very sensitive on the exact value of $\theta$. At the same time, the ab initio alignment to $\theta = 0^\circ$ has a limited precision in practice. We therefore adjust $\theta$ as close to $\theta = 0^\circ$ as possible before starting the experiment. After a trace like the one given in Fig. 2b is captured, we find the precise value of $\theta$ from a fit with $c_{\text{IRM}}$ given below. This constant value of $\theta$ is then used in the following analysis. We find and use $\theta = 1^\circ$ for the analysis given in Fig. 2. Since p- and s-polarization cannot be distinguished for normal incidence, $\gamma$ does not matter any more and we use $\gamma = 0^\circ$ for simplicity. From equation 3.12 we obtain the analytical expression for the normalized counts $c_{\text{IRM}}$ with $E_0 = 1$ as

$$c_{\text{IRM}} = \frac{\cos\left(\frac{2\pi \Delta p_{\text{air}}}{\lambda}\right) p_{\text{air}} (n_{\text{Si}} p_{\text{Dia}} - n_{\text{Dia}}^2 p_{\text{Si}}) - i \sin\left(\frac{2\pi \Delta p_{\text{air}}}{\lambda}\right) \left( p_{\text{Dia}} p_{\text{Si}} - n_{\text{Dia}}^2 n_{\text{Si}}^2 (1 - n_{\text{Dia}}^2 \sin(\theta)^2) \right)}{\cos\left(\frac{2\pi \Delta p_{\text{air}}}{\lambda}\right) p_{\text{air}} (n_{\text{Si}}^2 p_{\text{Dia}} + n_{\text{Dia}}^2 p_{\text{Si}}) - i \sin\left(\frac{2\pi \Delta p_{\text{air}}}{\lambda}\right) \left( p_{\text{Dia}} p_{\text{Si}} + n_{\text{Dia}}^2 n_{\text{Si}}^2 (1 - n_{\text{Dia}}^2 \sin(\theta)^2) \right)}.$$  

(3.13)
3 Derivation of fit functions

Where

\[ p_{\text{air}} = \sqrt{1 - n_{\text{Dia}}^2 \sin(\theta)^2} \]
\[ p_{\text{Si}} = \sqrt{n_{\text{Si}}^2 - n_{\text{Dia}}^2 \sin(\theta)^2} \]
\[ p_{\text{Dia}} = |\cos(\theta)| n_{\text{Dia}} \]  \hspace{1cm} (3.14)

The following values are used for the fix parameters:

\[ \lambda = 532 \text{ nm} \]
\[ n_{\text{Dia}} = 2.425 \]
\[ n_{\text{Si}} = 4.140 + 0.032i \]
\[ \theta = 1^\circ \]  \hspace{1cm} (3.15)

To fit the raw camera data, an additional offset and amplitude factor are added so that the fit function reads

\[ f_{\text{IRM}}(\Delta, A, b) = A \cdot c_{\text{IRM}} + b. \]  \hspace{1cm} (3.16)

For total internal reflection microscopy (TIRM), which is used for distance control in Fig. 3c, we move the focus in the back-focal plane so that \( \theta \) is larger than the total internal reflection angle of diamond to air (24.35°) and adjust \( \gamma = 45^\circ \), as this gives the highest sensitivity to \( \Delta \). Moreover, \( \alpha = 90^\circ \). From equation 3.12 we obtain the analytical expression for the normalized counts \( c_{\text{TIRM}} \) with \( E_0 = 1 \) as

\[
c_{\text{TIRM}} = \frac{\sin\left(\frac{2\pi \Delta_{\text{air}}}{\lambda}\right) \left( p_{\text{Dia}} p_{\text{Si}} - 1 + n_{\text{Dia}}^2 \sin(\theta)^2 \right) + i \cos\left(\frac{2\pi \Delta_{\text{air}}}{\lambda}\right) p_{\text{air}} (p_{\text{Dia}} - p_{\text{Si}})}{\left| \sin\left(\frac{2\pi \Delta_{\text{air}}}{\lambda}\right) \left( p_{\text{Dia}} p_{\text{Si}} + 1 - n_{\text{Dia}}^2 \sin(\theta)^2 \right) + i \cos\left(\frac{2\pi \Delta_{\text{air}}}{\lambda}\right) p_{\text{air}} (p_{\text{Dia}} + p_{\text{Si}}) \right|^2} \]
\[
+ \frac{\cos\left(\frac{2\pi \Delta_{\text{air}}}{\lambda}\right) p_{\text{air}} (n_{\text{Si}}^2 p_{\text{Dia}} - n_{\text{Dia}}^2 p_{\text{Si}}) - i \sin\left(\frac{2\pi \Delta_{\text{air}}}{\lambda}\right) \left( p_{\text{Dia}} p_{\text{Si}} - n_{\text{Dia}}^2 n_{\text{Si}}^2 \left( 1 - n_{\text{Dia}}^2 \sin(\theta)^2 \right) \right) \right|^2} {\cos\left(\frac{2\pi \Delta_{\text{air}}}{\lambda}\right) p_{\text{air}} (n_{\text{Si}}^2 p_{\text{Dia}} + n_{\text{Dia}}^2 p_{\text{Si}}) - i \sin\left(\frac{2\pi \Delta_{\text{air}}}{\lambda}\right) \left( p_{\text{Dia}} p_{\text{Si}} + n_{\text{Dia}}^2 n_{\text{Si}}^2 \left( 1 - n_{\text{Dia}}^2 \sin(\theta)^2 \right) \right)} \]  \hspace{1cm} (3.17)

To approach sample and probe to about 20 nm scanning distance, we first capture the camera counts for large \( \Delta \approx 1 \mu \text{m} \). In the following, a pre-calibrated background of about 4% of this value is always subtracted from the counts. Sample and probe are then approached until the camera counts \( C \) have dropped from 100% down to roughly \( C_{\text{fit}} = 15\% \) (c.f. Fig. 3c of the main text). Then, the following function is fitted to the captured data with \( C > C_{\text{fit}} \):

\[ f_{\text{TIRM}}(\Delta, \theta, A) = A \cdot c_{\text{TIRM}} \]  \hspace{1cm} (3.18)

The fitted function can now be used to extrapolate the trace down to \( \Delta = 0 \) nm, allowing for a controlled and quantitative approach. This procedure is robust against selection of different starting points for the extrapolation. We find the predicted contact point of this extrapolation to fluctuate well below 5 nm for all data ranges \( C > C_{\text{fit}} \) with \( C_{\text{fit}} \) between 5% and 25%.
4 Analysis of NV–wire near–field interaction

**Figure S4:** Line cut of a near-field scan produced by an NV center scanning over an Ag nanowire. All data is extracted from Fig 4b main manuscript. PL: photo-luminescence. a) We distort the near-field image to align the nanowire vertically. A line cut of the fluorescence intensity is then extracted by summing along the vertical axis. b) Line cut extracted from a by vertical averaging (dashed line) along with the data of a single horizontal line (dots) from the vertical center of a. Near-field features are embedded in a broad diffraction-limited peak, which we attribute to local amplification of the excitation laser. Near-field interaction with the wire leads to dark lines much smaller than the diffraction limit, induced by quenching of the NV fluorescence. The double-dip feature and the asymmetric shape arises from competing mechanisms in the NV-wire interaction (see text).

The near-field image of Fig. 4 is a complex pattern of dark and bright stripes, with surprising features such as a strong asymmetry. We now turn to a more detailed analysis of these features, and comment on the physical effects that are likely to play a role. To this end, we extracted a one-dimensional line-cut from the soft-contact scan of Fig. 4 of the main manuscript (Fig. S4). In a first step, the data has to be distorted to align the wire with the coordinate axes (Fig. S4 a). We do this by shifting every horizontal line by an offset $\Delta x$ that depends on the vertical position $y$ according to the equation

$$\Delta x = \alpha y + \beta y^2.$$ 

The parameters $\alpha$ and $\beta$ are adjusted manually to values of $\alpha = 0.716 \text{ px/px}$, $\beta = 7 \times 10^{-4} \text{ px/px}^2$. We subsequently create a line cut by summing the corrected data along the vertical direction. A sample of 100 lines from the central area of Fig. S4 a is used for this purpose. We scale the x-axis by a factor $1/\sqrt{1 + \alpha^2}$ in a final step to account for the
Analysis of NV–wire near–field interaction

fact that the wire is not aligned parallel to the coordinate axes in the original near-field scan. This artefact is not removed by our distortion procedure, which is based on shifting adjacent lines rather than a rotation of the image.

The resulting profile reveals a number of features. First, the NV luminescence is enhanced within a broad interval of roughly diffraction-limited size. We attribute this to amplification of the excitation laser. Two narrow dips are visible within this broad feature, where fluorescence drops below the level obtained far from the wire. We attribute these sub-diffraction features to quenching of the NV center by coupling to plasmonic modes in the wire, which is confirmed by the observation that fluorescence lifetime is reduced at these points (Fig. 4d). The emergence of two distinct dips is most likely owing to a competition of several effects. Purcell enhancement or quenching of the NV luminescence can have a complex pattern, because the NV axis is misaligned with respect to the diamond surface normal and because the NV center has two emission dipoles. They lie in the plane perpendicular to its axis, but have an unknown orientation within this plane. Additionally, Purcell-type effects compete with changes in the spatial mode of the NV emission induced by the wire. These equally lead to a change in fluorescence, since different modes have different overlap with the detection mode of the microscope. If all of these mechanisms reach their peak strength at different positions, a complex profile can arise. The asymmetry of the profile is most likely owing to the fact that several experimental parameters, in particular the orientation of the NV axis and its transition dipoles, break mirror symmetry.
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