Atomic physics from an electromagnetics point of view: an appetizer

Francesco Lorenzi

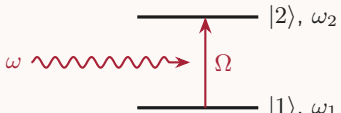
Department of Information Engineering, University of Padova

PEG group meeting – DEI, University of Padova – 30 September 2026

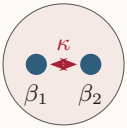


An atom and a two-core fiber

[C. Giles et al., J. Lightwave Technol. 9, 271–283 (1991)]
[M. Koshiba et al., *Opt. Express* 19, B102 (2011)]



atom in a plane wave



two-core fiber

unperturbed frequency	level frequency $\omega_n = E_n/\hbar$	propagation constant $\beta_n = 2\pi n_{\text{eff}}/\lambda$
coupling	dipole coupling $\lvert\Omega\rvert = \lvert d_{21}\rvert E_0/\hbar$	mode-overlap coupling κ
frequency fluctuations	atomic collisions, laser phase noise	bends, twist, core-radius fluctuations

1 coupled-amplitude equation $\longrightarrow$ **2** phase noise: averaged equation $\longrightarrow$ **3** rate equations

Two cores: the coupled-mode equation

[H. Haus et al., Proc. IEEE 79, 1505–1518 (1991)]
[A. W. Snyder, *J. Opt. Soc. Am.* 62, 1267 (1972)]

1 isolated cores

$$\mathbf{E}_n = \mathbf{e}_n(x,y)\,\mathrm{e}^{j(\omega t-\beta_n z)}$$

2 coupled cores

$$\mathbf{E} = \sum_n b_n(z)\,\mathbf{e}_n(x,y)\,\mathrm{e}^{j\omega t}$$

substitute into Maxwell's equations; for the mode of core 1, core 2 is a permittivity perturbation $\Delta\varepsilon$; project onto each mode $\mathbf{e}_m$

$$j\,\partial_z \begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} \beta_1 & \kappa \\ \kappa^* & \beta_2 \end{pmatrix} \begin{pmatrix} b_1 \\ b_2 \end{pmatrix}, \qquad \kappa = \frac{\omega}{4} \iint \mathbf{e}_1^* \cdot \Delta\varepsilon\,\mathbf{e}_2\,\mathrm{d}x\,\mathrm{d}y$$

3 input in core 1: $b(0) = (1,0)$

$$|b_2(z)|^2 = \frac{|\kappa|^2}{\bar\kappa^2}\sin^2\bar\kappa z, \qquad \bar\kappa^2 = |\kappa|^2 + \frac{\Delta\beta^2}{4}, \qquad \Delta\beta = \beta_1 - \beta_2$$

complete power transfer requires $\Delta\beta = 0$ and occurs at $z = L_c = \pi/(2|\kappa|)$

Physical origin of the entries

$\beta_n = 2\pi n_{\mathrm{eff}}/\lambda$	core index and radius
$\lvert\kappa\rvert \propto \mathrm{e}^{-\Lambda/\delta}$	core pitch Λ, tail length δ
$\Delta\beta \simeq \beta\,\Lambda/R$	bend radius R

Two cores: the coupled-mode equation

[H. Haus et al., Proc. IEEE 79, 1505–1518 (1991)]
[A. W. Snyder, *J. Opt. Soc. Am.* 62, 1267 (1972)]

1 isolated cores

$$\mathbf{E}_n = \mathbf{e}_n(x,y)\,\mathrm{e}^{j(\omega t-\beta_n z)}$$

2 coupled cores

$$\mathbf{E} = \textstyle\sum_n b_n(z)\,\mathbf{e}_n(x,y)\,\mathrm{e}^{j\omega t}$$

substitute into Maxwell's equations; for the mode of core 1, core 2 is a permittivity perturbation $\Delta\varepsilon$; project onto each mode $\mathbf{e}_m$

$$j\,\partial_z \begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} \beta_1 & \kappa \\ \kappa^* & \beta_2 \end{pmatrix} \begin{pmatrix} b_1 \\ b_2 \end{pmatrix}, \qquad \kappa = \frac{\omega}{4}\iint \mathbf{e}_1^* \cdot \Delta\varepsilon\,\mathbf{e}_2\,\mathrm{d}x\,\mathrm{d}y$$

3 input in core 1: $b(0) = (1,0)$

$$|b_2(z)|^2 = \frac{|\kappa|^2}{\bar\kappa^2}\sin^2\bar\kappa z, \qquad \bar\kappa^2 = |\kappa|^2 + \frac{\Delta\beta^2}{4}, \qquad \Delta\beta = \beta_1 - \beta_2$$

complete power transfer requires $\Delta\beta = 0$ and occurs at $z = L_c = \pi/(2|\kappa|)$

Physical origin of the entries

$\beta_n = 2\pi n_{\mathrm{eff}}/\lambda$	core index and radius
$\lvert\kappa\rvert \propto \mathrm{e}^{-\Lambda/\delta}$	core pitch Λ, tail length δ
$\Delta\beta \simeq \beta\,\Lambda/R$	bend radius R

Two cores: the coupled-mode equation

[H. Haus et al., Proc. IEEE 79, 1505–1518 (1991)]
[A. W. Snyder, *J. Opt. Soc. Am.* 62, 1267 (1972)]

1 isolated cores

$$\mathbf{E}_n = \mathbf{e}_n(x,y)\,\mathrm{e}^{j(\omega t-\beta_n z)}$$

2 coupled cores

$$\mathbf{E} = \textstyle\sum_n b_n(z)\,\mathbf{e}_n(x,y)\,\mathrm{e}^{j\omega t}$$

substitute into Maxwell's equations; for the mode of core 1, core 2 is a permittivity perturbation $\Delta\varepsilon$; project onto each mode $\mathbf{e}_m$

$$j\,\partial_z \begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} \beta_1 & \kappa \\ \kappa^* & \beta_2 \end{pmatrix} \begin{pmatrix} b_1 \\ b_2 \end{pmatrix}, \qquad \kappa = \frac{\omega}{4} \iint \mathbf{e}_1^* \cdot \Delta\varepsilon\, \mathbf{e}_2 \,\mathrm{d}x\,\mathrm{d}y$$

3 input in core 1: $b(0) = (1,0)$

$$|b_2(z)|^2 = \frac{|\kappa|^2}{\bar\kappa^2}\sin^2\bar\kappa z, \qquad \bar\kappa^2 = |\kappa|^2 + \frac{\Delta\beta^2}{4}, \qquad \Delta\beta = \beta_1 - \beta_2$$

complete power transfer requires $\Delta\beta = 0$ and occurs at $z = L_c = \pi/(2|\kappa|)$

Physical origin of the entries

$\beta_n = 2\pi n_{\mathrm{eff}}/\lambda$	core index and radius
$\lvert\kappa\rvert \propto \mathrm{e}^{-\Lambda/\delta}$	core pitch Λ, tail length δ
$\Delta\beta \simeq \beta\,\Lambda/R$	bend radius R

An atom in a plane wave: the same equation

[R. P. Feynman et al., J. Appl. Phys. 28, 49–52 (1957)]
[G. Allinson et al., arXiv:2601.20631 (2026)]

1 unperturbed atom

$|\psi\rangle = \sum_n C_n(t)|n\rangle, \qquad C_n \propto \mathrm{e}^{-i\omega_n t}$

2 plane wave $\mathbf{E} = E_0\hat{\mathbf{e}}\cos\omega t$

↓ add the dipole interaction $-\hat{\mathbf{d}}\cdot\mathbf{E}$ to the Hamiltonian; project Schrödinger's equation onto each level $\langle m|$

$$i\,\partial_t C_m = \omega_m C_m - \sum_n \frac{\langle m|\hat{\mathbf{d}}|n\rangle\cdot\mathbf{E}(t)}{\hbar}\,C_n$$

↓ rotating-wave approximation: retain only the term of $\cos\omega t$ resonant with $1 \to 2$; $\tilde{C}_1 = C_1\mathrm{e}^{-i\omega t}$: level 1 plus one absorbed photon, frequency $\omega_1 + \omega$

$$i\,\partial_t\begin{pmatrix}\tilde{C}_1\\ C_2\end{pmatrix} = \begin{pmatrix}\omega_1+\omega & \Omega^*/2\\ \Omega/2 & \omega_2\end{pmatrix}\begin{pmatrix}\tilde{C}_1\\ C_2\end{pmatrix}$$

with $\Omega = -d_{21}E_0/\hbar$, $d_{21} = \langle 2|\hat{\mathbf{d}}|1\rangle\cdot\hat{\mathbf{e}}$

3 initial state $|1\rangle$: $C(0) = (1,0)$

$$|C_2(t)|^2 = \frac{|\Omega|^2}{\Omega'^2}\sin^2\frac{\Omega' t}{2}, \qquad \Omega'^2 = |\Omega|^2 + \Delta^2$$

Physical origin of the entries

$\omega_{21} \propto n^{-3}$	principal quantum number n
$\lvert\Omega\rvert \propto n^2 E_0$	dipole $\lvert d_{21}\rvert \propto n^2 e a_0$
$\Delta = \omega - \omega_{21}$	detuning of the wave

An atom in a plane wave: the same equation

[R. P. Feynman et al., J. Appl. Phys. 28, 49–52 (1957)]
[G. Allinson et al., arXiv:2601.20631 (2026)]

1 unperturbed atom

$|\psi\rangle = \sum_n C_n(t)|n\rangle, \qquad C_n \propto \mathrm{e}^{-i\omega_n t}$

2 plane wave $\mathbf{E} = E_0\hat{\mathbf{e}}\cos\omega t$

↓ add the dipole interaction $-\hat{\mathbf{d}}\cdot\mathbf{E}$ to the Hamiltonian; project Schrödinger's equation onto each level $\langle m|$

$$i\,\partial_t C_m = \omega_m C_m - \sum_n \frac{\langle m|\hat{\mathbf{d}}|n\rangle\cdot\mathbf{E}(t)}{\hbar}\,C_n$$

↓ rotating-wave approximation: retain only the term of $\cos\omega t$ resonant with $1 \to 2$; $\tilde{C}_1 = C_1\mathrm{e}^{-i\omega t}$: level 1 plus one absorbed photon, frequency $\omega_1 + \omega$

$$i\,\partial_t\begin{pmatrix}\tilde{C}_1\\ C_2\end{pmatrix} = \begin{pmatrix}\omega_1+\omega & \Omega^*/2\\ \Omega/2 & \omega_2\end{pmatrix}\begin{pmatrix}\tilde{C}_1\\ C_2\end{pmatrix}$$

with $\Omega = -d_{21}E_0/\hbar$, $d_{21} = \langle 2|\hat{\mathbf{d}}|1\rangle\cdot\hat{\mathbf{e}}$

3 initial state $|1\rangle$: $C(0) = (1,0)$

$$|C_2(t)|^2 = \frac{|\Omega|^2}{\Omega'^2}\sin^2\frac{\Omega' t}{2}, \qquad \Omega'^2 = |\Omega|^2 + \Delta^2$$

Physical origin of the entries

$\omega_{21} \propto n^{-3}$	principal quantum number n
$\lvert\Omega\rvert \propto n^2 E_0$	dipole $\lvert d_{21}\rvert \propto n^2 e a_0$
$\Delta = \omega - \omega_{21}$	detuning of the wave

An atom in a plane wave: the same equation

[R. P. Feynman et al., J. Appl. Phys. 28, 49–52 (1957)]
[G. Allinson et al., arXiv:2601.20631 (2026)]

1 unperturbed atom

$|\psi\rangle = \sum_n C_n(t)|n\rangle, \qquad C_n \propto \mathrm{e}^{-i\omega_n t}$

2 plane wave $\mathbf{E} = E_0\hat{\mathbf{e}}\cos\omega t$

↓ add the dipole interaction $-\hat{\mathbf{d}}\cdot\mathbf{E}$ to the Hamiltonian; project Schrödinger's equation onto each level $\langle m|$

$$i\,\partial_t C_m = \omega_m C_m - \sum_n \frac{\langle m|\hat{\mathbf{d}}|n\rangle\cdot\mathbf{E}(t)}{\hbar}\,C_n$$

↓ rotating-wave approximation: retain only the term of $\cos\omega t$ resonant with $1 \to 2$; $\tilde{C}_1 = C_1\mathrm{e}^{-i\omega t}$: level 1 plus one absorbed photon, frequency $\omega_1 + \omega$

$$i\,\partial_t\begin{pmatrix}\tilde{C}_1\\ C_2\end{pmatrix} = \begin{pmatrix}\omega_1+\omega & \Omega^*/2\\ \Omega/2 & \omega_2\end{pmatrix}\begin{pmatrix}\tilde{C}_1\\ C_2\end{pmatrix}$$

with $\Omega = -d_{21}E_0/\hbar$, $d_{21} = \langle 2|\hat{\mathbf{d}}|1\rangle\cdot\hat{\mathbf{e}}$

3 initial state $|1\rangle$: $C(0) = (1,0)$

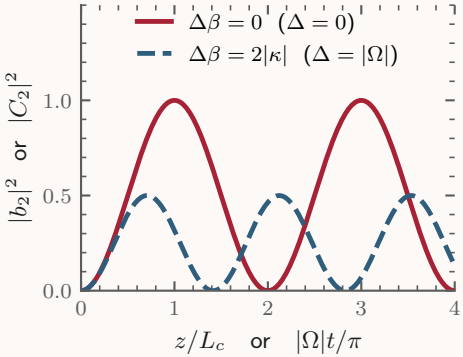
$$|C_2(t)|^2 = \frac{|\Omega|^2}{\Omega'^2}\sin^2\frac{\Omega' t}{2}, \quad \Omega'^2 = |\Omega|^2 + \Delta^2$$

Physical origin of the entries

$\omega_{21} \propto n^{-3}$	principal quantum number n
$\lvert\Omega\rvert \propto n^2 E_0$	dipole $\lvert d_{21}\rvert \propto n^2 e a_0$
$\Delta = \omega - \omega_{21}$	detuning of the wave

One equation, two systems

	two-core fiber	atom in a plane wave
evolution variable	z	t
diagonal entries	$\beta_1,\ \beta_2$	$\omega_1+\omega,\ \omega_2$
off-diagonal entries	κ	$\Omega^*/2$
detuning	$\Delta\beta=\beta_1-\beta_2$	$\Delta=\omega-\omega_{21}$
coherent exchange	coupler beat	Rabi oscillation
complete transfer	$L_c=\pi/(2\lvert\kappa\rvert)$	π pulse, $t=\pi/\lvert\Omega\rvert$
equal split	3 dB coupler	$\pi/2$ pulse
eigenstates	supermodes	dressed states



Phase noise: the averaged equation

[R. Kubo, *J. Math. Phys.* 4, 174–183 (1963)] [H. Haken et al., *Z. Phys.* 262, 135–148 (1973)]

$\beta_2 \to \beta_2 + \xi(z)$ (random), $\langle\cdot\rangle$: average over fibers, $P_n = \langle |b_n|^2 \rangle$, $c = \langle b_1 b_2^* \rangle$

1 one fiber

$$\frac{\mathrm{d}|b_2|^2}{\mathrm{d}z} = 2\,\mathrm{Im}\big(\kappa^* b_1 b_2^*\big) = -\frac{\mathrm{d}|b_1|^2}{\mathrm{d}z}, \qquad \frac{\mathrm{d}(b_1 b_2^*)}{\mathrm{d}z} = -j\,(\Delta\beta - \xi)\,b_1 b_2^* + j\kappa\left(|b_1|^2 - |b_2|^2\right)$$

2 over a short length Δz, ξ rotates the phase of $b_1 b_2^*$ by $\delta\phi = \int_z^{z+\Delta z} \xi\,\mathrm{d}z'$

$$\langle \delta\phi^2 \rangle = 2\gamma\Delta z \quad \Rightarrow \quad \langle \mathrm{e}^{j\delta\phi} \rangle = \mathrm{e}^{-\gamma\Delta z} \simeq 1 - \gamma\Delta z$$

3 the averaged equation (atoms: optical Bloch equations)

$$\frac{\mathrm{d}P_2}{\mathrm{d}z} = 2\,\mathrm{Im}\big(\kappa^* c\big) = -\frac{\mathrm{d}P_1}{\mathrm{d}z}, \qquad \frac{\mathrm{d}c}{\mathrm{d}z} = -(\gamma + j\Delta\beta)\,c + j\kappa\,(P_1 - P_2)$$

Phase noise: the averaged equation

[R. Kubo, *J. Math. Phys.* 4, 174–183 (1963)] [H. Haken et al., *Z. Phys.* 262, 135–148 (1973)]

$\beta_2 \to \beta_2 + \xi(z)$ (random), $\langle\cdot\rangle$: average over fibers, $P_n = \langle |b_n|^2 \rangle$, $c = \langle b_1 b_2^* \rangle$

1 one fiber

$$\frac{\mathrm{d}|b_2|^2}{\mathrm{d}z} = 2\,\mathrm{Im}\big(\kappa^* b_1 b_2^*\big) = -\frac{\mathrm{d}|b_1|^2}{\mathrm{d}z}, \qquad \frac{\mathrm{d}(b_1 b_2^*)}{\mathrm{d}z} = -j\,(\Delta\beta - \xi)\,b_1 b_2^* + j\kappa\left(|b_1|^2 - |b_2|^2\right)$$

2 over a short length Δz, ξ rotates the phase of $b_1 b_2^*$ by $\delta\phi = \int_z^{z+\Delta z} \xi\,\mathrm{d}z'$

$$\langle \delta\phi^2 \rangle = 2\gamma\Delta z \quad \Rightarrow \quad \langle \mathrm{e}^{j\delta\phi} \rangle = \mathrm{e}^{-\gamma\Delta z} \simeq 1 - \gamma\Delta z$$

3 the averaged equation (atoms: optical Bloch equations)

$$\frac{\mathrm{d}P_2}{\mathrm{d}z} = 2\,\mathrm{Im}\big(\kappa^* c\big) = -\frac{\mathrm{d}P_1}{\mathrm{d}z}, \qquad \frac{\mathrm{d}c}{\mathrm{d}z} = -(\gamma + j\Delta\beta)\,c + j\kappa\,(P_1 - P_2)$$

Phase noise: the averaged equation

[R. Kubo, *J. Math. Phys.* 4, 174–183 (1963)] [H. Haken et al., *Z. Phys.* 262, 135–148 (1973)]

$\beta_2 \to \beta_2 + \xi(z)$ (random), $\langle\cdot\rangle$: average over fibers, $P_n = \langle |b_n|^2 \rangle$, $c = \langle b_1 b_2^* \rangle$

1 one fiber

$$\frac{\mathrm{d}|b_2|^2}{\mathrm{d}z} = 2\,\mathrm{Im}\big(\kappa^* b_1 b_2^*\big) = -\frac{\mathrm{d}|b_1|^2}{\mathrm{d}z}, \qquad \frac{\mathrm{d}(b_1 b_2^*)}{\mathrm{d}z} = -j\,(\Delta\beta - \xi)\,b_1 b_2^* + j\kappa\left(|b_1|^2 - |b_2|^2\right)$$

2 over a short length Δz, ξ rotates the phase of $b_1 b_2^*$ by $\delta\phi = \int_z^{z+\Delta z} \xi\,\mathrm{d}z'$

$$\langle \delta\phi^2 \rangle = 2\gamma\Delta z \quad \Rightarrow \quad \langle \mathrm{e}^{j\delta\phi} \rangle = \mathrm{e}^{-\gamma\Delta z} \simeq 1 - \gamma\Delta z$$

3 the averaged equation (atoms: optical Bloch equations)

$$\frac{\mathrm{d}P_2}{\mathrm{d}z} = 2\,\mathrm{Im}\big(\kappa^* c\big) = -\frac{\mathrm{d}P_1}{\mathrm{d}z}, \qquad \frac{\mathrm{d}c}{\mathrm{d}z} = -(\gamma + j\Delta\beta)\,c + j\kappa\,(P_1 - P_2)$$

Strong phase noise: coupled-power theory

[D. Marcuse, *Bell Syst. Tech. J.* 51, 229–237 (1972)]
[M. Koshiba et al., *Opt. Express* 19, B102 (2011)]

$\gamma \gg |\kappa|$: c **relaxes within a length** $1/\gamma$**, before the powers change appreciably**

↓ set $\mathrm{d}c/\mathrm{d}z \simeq 0$ in the averaged equation

$$c \simeq \frac{j\kappa\,(P_1 - P_2)}{\gamma + j\Delta\beta}$$

↓ substitute into $\mathrm{d}P_2/\mathrm{d}z = 2\,\mathrm{Im}(\kappa^* c)$

$$\frac{\mathrm{d}P_2}{\mathrm{d}z} = h\,(P_1 - P_2), \qquad h = \frac{2|\kappa|^2\gamma}{\gamma^2 + \Delta\beta^2}$$

input in core 1: $P_2(z) = \frac{1}{2}\left(1 - \mathrm{e}^{-2hz}\right)$

Strong phase noise: coupled-power theory

[D. Marcuse, *Bell Syst. Tech. J.* 51, 229–237 (1972)]
[M. Koshiba et al., *Opt. Express* 19, B102 (2011)]

$\gamma \gg |\kappa|$: **c relaxes within a length $1/\gamma$, before the powers change appreciably**

↓ set $\mathrm{d}c/\mathrm{d}z \simeq 0$ in the averaged equation

$$c \simeq \frac{j\kappa\,(P_1 - P_2)}{\gamma + j\Delta\beta}$$

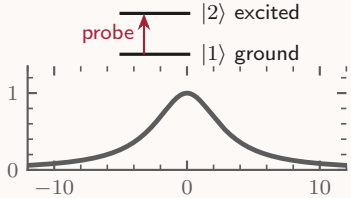
↓ substitute into $\mathrm{d}P_2/\mathrm{d}z = 2\,\mathrm{Im}(\kappa^* c)$

$$\frac{\mathrm{d}P_2}{\mathrm{d}z} = h\,(P_1 - P_2), \qquad h = \frac{2|\kappa|^2\gamma}{\gamma^2 + \Delta\beta^2}$$

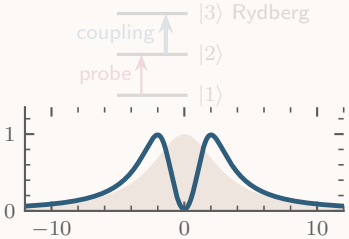
input in core 1: $P_2(z) = \frac{1}{2}\left(1 - \mathrm{e}^{-2hz}\right)$

Rydberg sensor: working principle

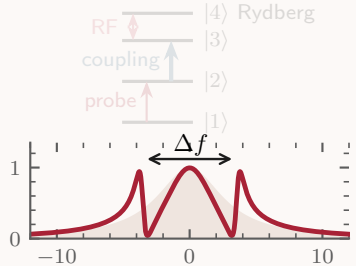
[S. H. Autler et al., *Phys. Rev.* 100, 703–722 (1955)] [M. Fleischhauer et al., *Rev. Mod. Phys.* 77, 633–673 (2005)] [J. A. Sedlacek et al., *Nat. Phys.* 8, 819–824 (2012)] [C. L. Holloway et al., IEEE Trans. Antennas Propag. 62, 6169–6182 (2014)]



probe only: absorption line



+ **coupling laser:** transparency window (EIT)



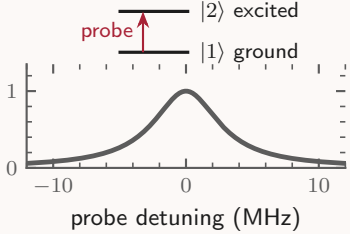
+ **RF field:** the window splits by $\Delta f \propto E_{\mathrm{RF}}$ (Autler–Townes)

$E_{\mathrm{RF}} = h\,\Delta f / d$, d: dipole of the Rydberg transition

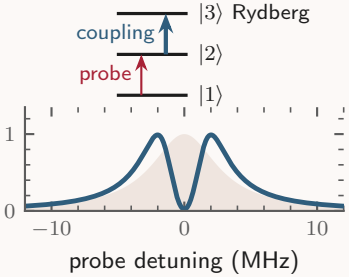
computed: weak probe, atoms at rest

Rydberg sensor: working principle

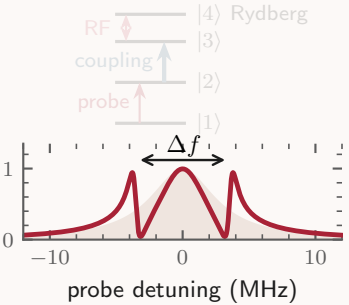
[S. H. Autler et al., *Phys. Rev.* 100, 703–722 (1955)] [M. Fleischhauer et al., *Rev. Mod. Phys.* 77, 633–673 (2005)] [J. A. Sedlacek et al., *Nat. Phys.* 8, 819–824 (2012)] [C. L. Holloway et al., IEEE Trans. Antennas Propag. 62, 6169–6182 (2014)]



probe only: absorption line



+ **coupling laser:** transparency window (EIT)



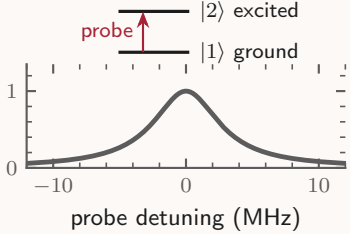
+ **RF field:** the window splits by $\Delta f \propto E_{\mathrm{RF}}$ (Autler–Townes)

$E_{\mathrm{RF}} = h\,\Delta f / d$, d: dipole of the Rydberg transition

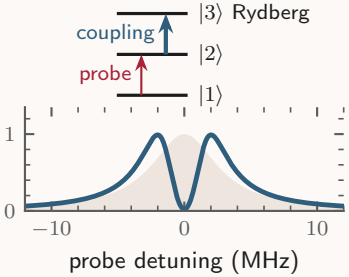
computed: weak probe, atoms at rest

Rydberg sensor: working principle

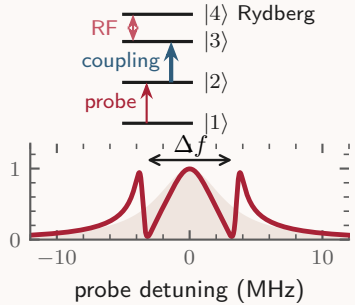
[S. H. Autler et al., *Phys. Rev.* 100, 703–722 (1955)] [M. Fleischhauer et al., *Rev. Mod. Phys.* 77, 633–673 (2005)] [J. A. Sedlacek et al., *Nat. Phys.* 8, 819–824 (2012)] [C. L. Holloway et al., IEEE Trans. Antennas Propag. 62, 6169–6182 (2014)]



probe only: absorption line



+ **coupling laser:** transparency window (EIT)



+ **RF field:** the window splits by $\Delta f \propto E_{\mathrm{RF}}$ (Autler–Townes)

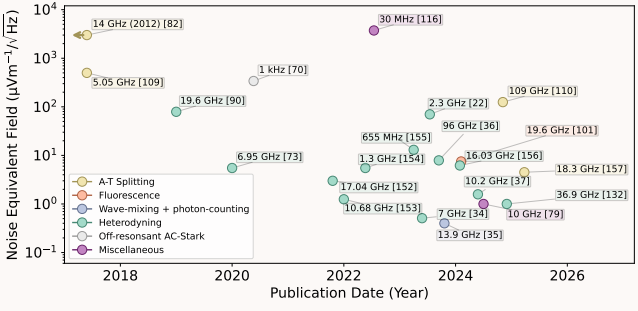
$$E_{\mathrm{RF}} = h\,\Delta f / d, \quad d\text{: dipole of the Rydberg transition}$$

computed: weak probe, atoms at rest

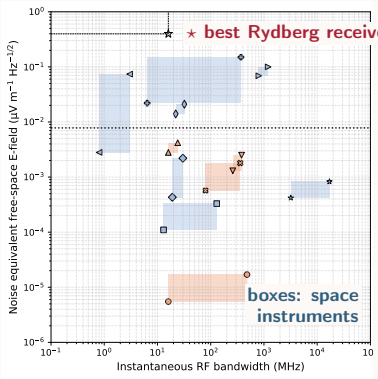
Rydberg RF receivers: where they stand

[G. Allinson et al., arXiv:2601.20631 (2026)]

reported noise-equivalent field versus year



requirements of spaceborne receivers



Plots from [G. Allinson et al., arXiv:2601.20631 (2026)]; noise-equivalent field in $\mu\mathrm{V\,m^{-1}\,Hz^{-1/2}}$

Conclusions

coherent regime	$\Longrightarrow$	one 2×2 equation: frequencies on the diagonal, couplings off-diagonal
two cores $\leftrightarrow$ atom	$\Longrightarrow$	$\beta_1,\ \beta_2,\ \kappa\ \leftrightarrow\ \omega_1 + \omega,\ \omega_2,\ \Omega^*/2$
phase noise, strength γ	$\Longrightarrow$	the relative phase decorrelates over a length $1/\gamma$
$\gamma \gg \lvert\kappa\rvert$	$\Longrightarrow$	coupled-power theory, $h = 2\lvert\kappa\rvert^2\gamma/(\gamma^2 + \Delta\beta^2)$

multicore-fiber crosstalk and atomic rate equations: the same strong-dephasing limit

Thank you!