1. Principle of the simulator SPECTROSIM

Aim: **explain the principle of light-matter interaction that is used in an atomic clock.**

- **Manipulate the principle characteristic parameters of an atomic clock.**
- **Understand their influence on the signal and the clock stability.**

The simulator:

- **can be operated according to the principles Rabi and Ramsey;**
- **and allows to visualize the influence of:**
  - **the interaction times,**
  - **the detection noise,**
  - **a probabilistic distribution of interaction times.**

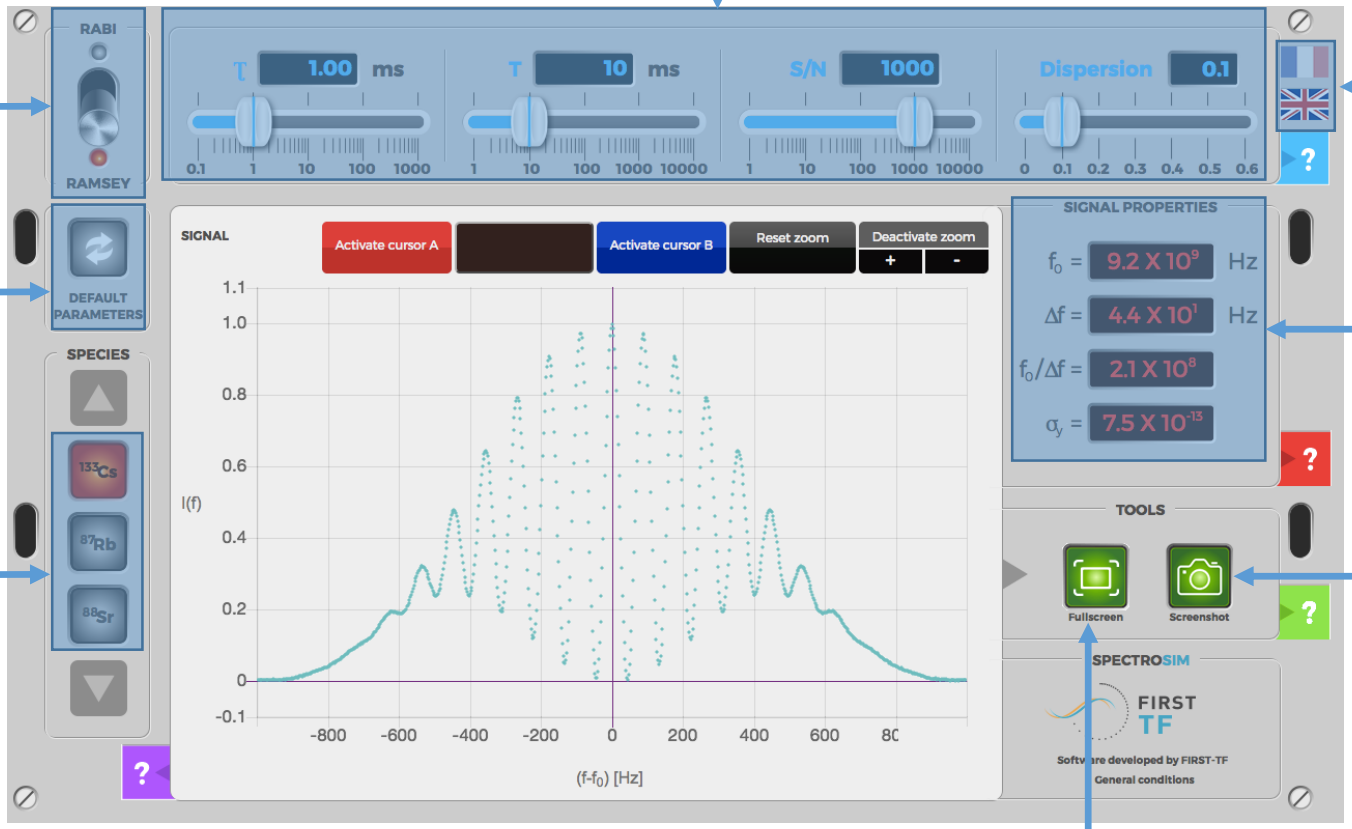
2. Structure of the graphical interface

Input of the parameters (via keyboard or fader)

Choice of Rabi or Ramsey dynamics

Reloading the initial values of all parameters

Selection of the atomic species



Language selection

Some properties of the displayed signal

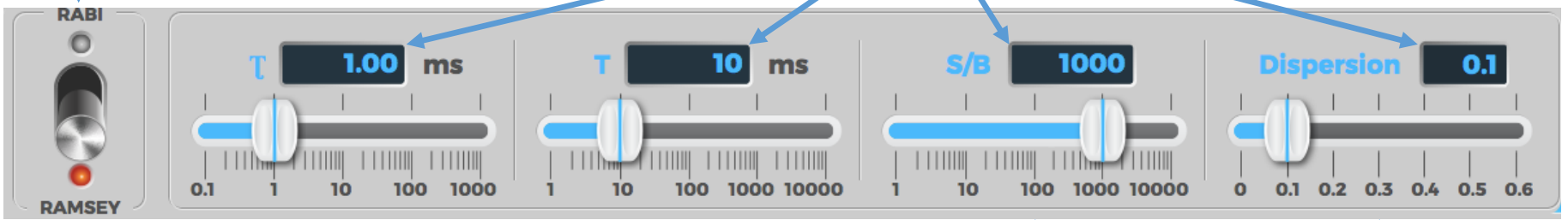
Possibility to take screenshots of the current signal

Fullscreen mode

3. Input of the parameters

Click to change
between Rabi and Ramsey

Click inside the fields to
enter values by keyboard



τ: duration of interaction between the atom and the field

T: dead time between two interactions (only in mode Ramsey)

S/N:
signal-to-noise ratio

Dispersion: this parameter estimates the relative width of a pseudo-thermal distribution of the interaction times.

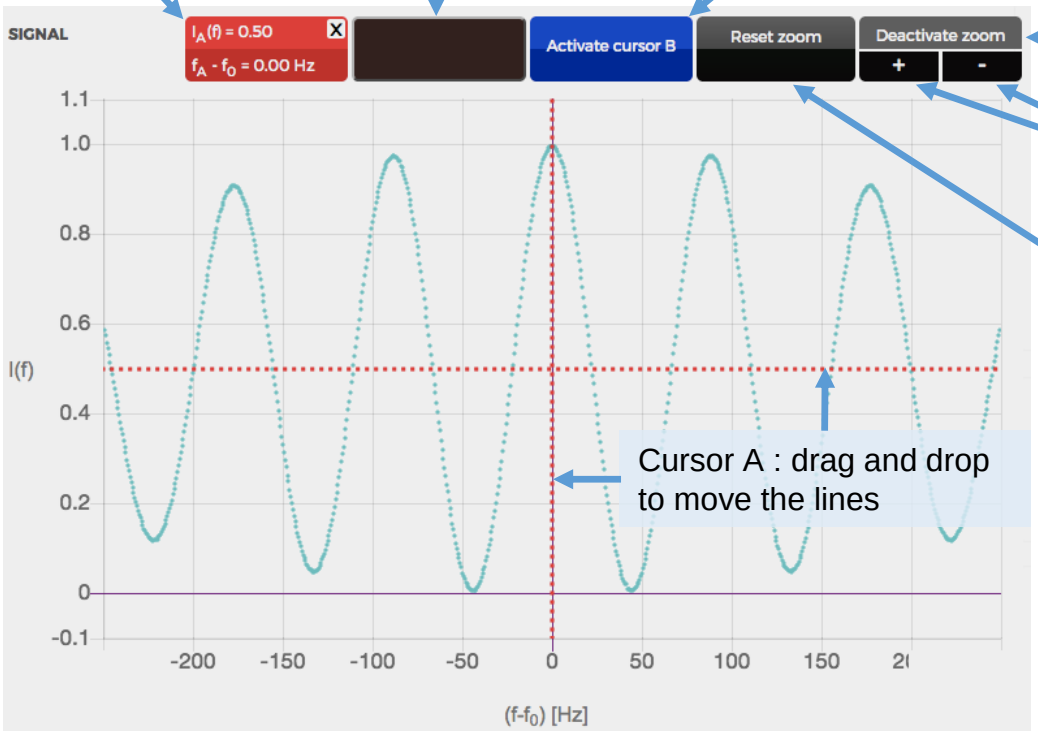
Note: The program allows also for parameters that do not correspond to a realistic situation.

4. Display of the signal

Coordinates of cursor (click to remove cursor)

Difference between coordinates of A and B

Resets zoom to its initial value



Allows to deactivate the zoom if it bothers the use of the simulator

Logarithmic zoom
« + » = x^2
« - » = $\sqrt{x}$

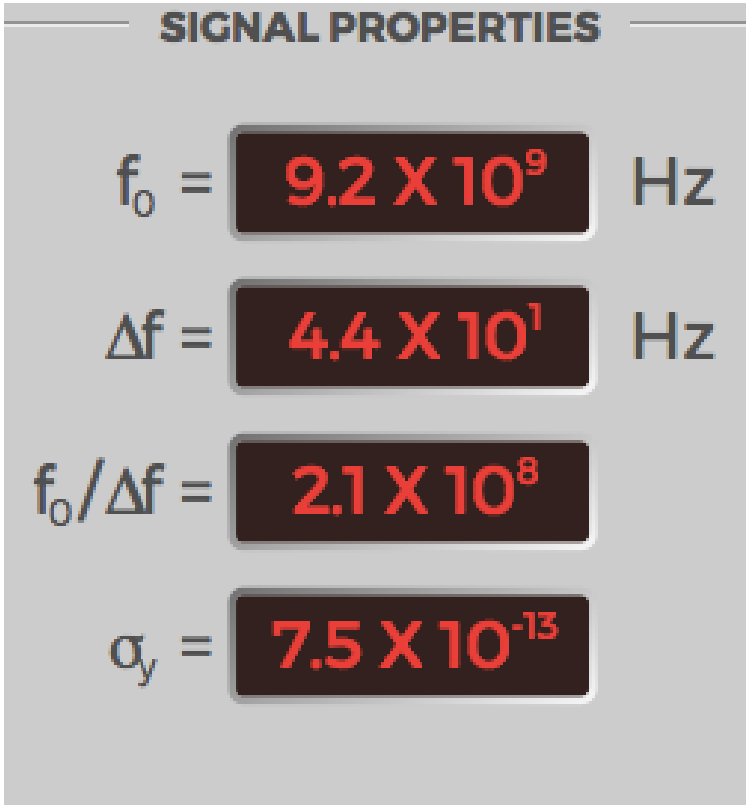
Click to activate cursor B

Signal = transition rate

Cursor A : drag and drop to move the lines

Difference between the atomic resonance frequency and the frequency of the electromagnetic wave

5. The signal properties



f_0: resonance frequency of the chosen atom

Δf: linewidth (of the central fringe in Ramsey mode)

f_0 / Δf: Quality factor Q

σ_y: quantity which gives a measure of the mean amplitude of frequency fluctuations of an oscillator stabilised to the spectral line in this configuration

6. Limits of the simulation

The simulator calculates the signal based on a model with several simplifications:

- **We assume that the central frequency always coincides with the atomic resonance frequency. In reality, perturbations like magnetic fields can lead to systematic shifts.**

- **The atoms are modelled as two-level atoms. In reality, there are always numerous other levels in the energy structure of an atom. The presence of a third level can be neglected if the linewidth is small compared to the gap between each of the two levels and the third levels. In atomic clocks this is usually the case.**