

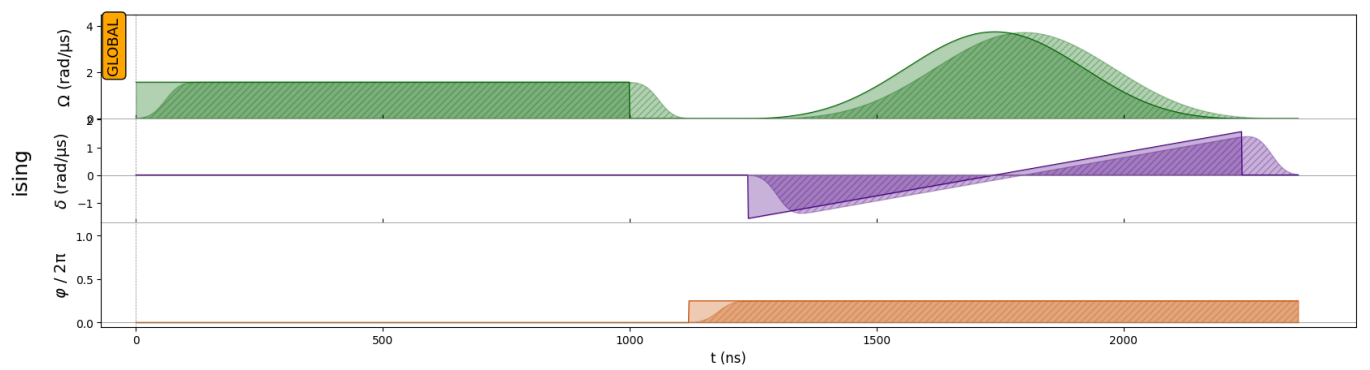
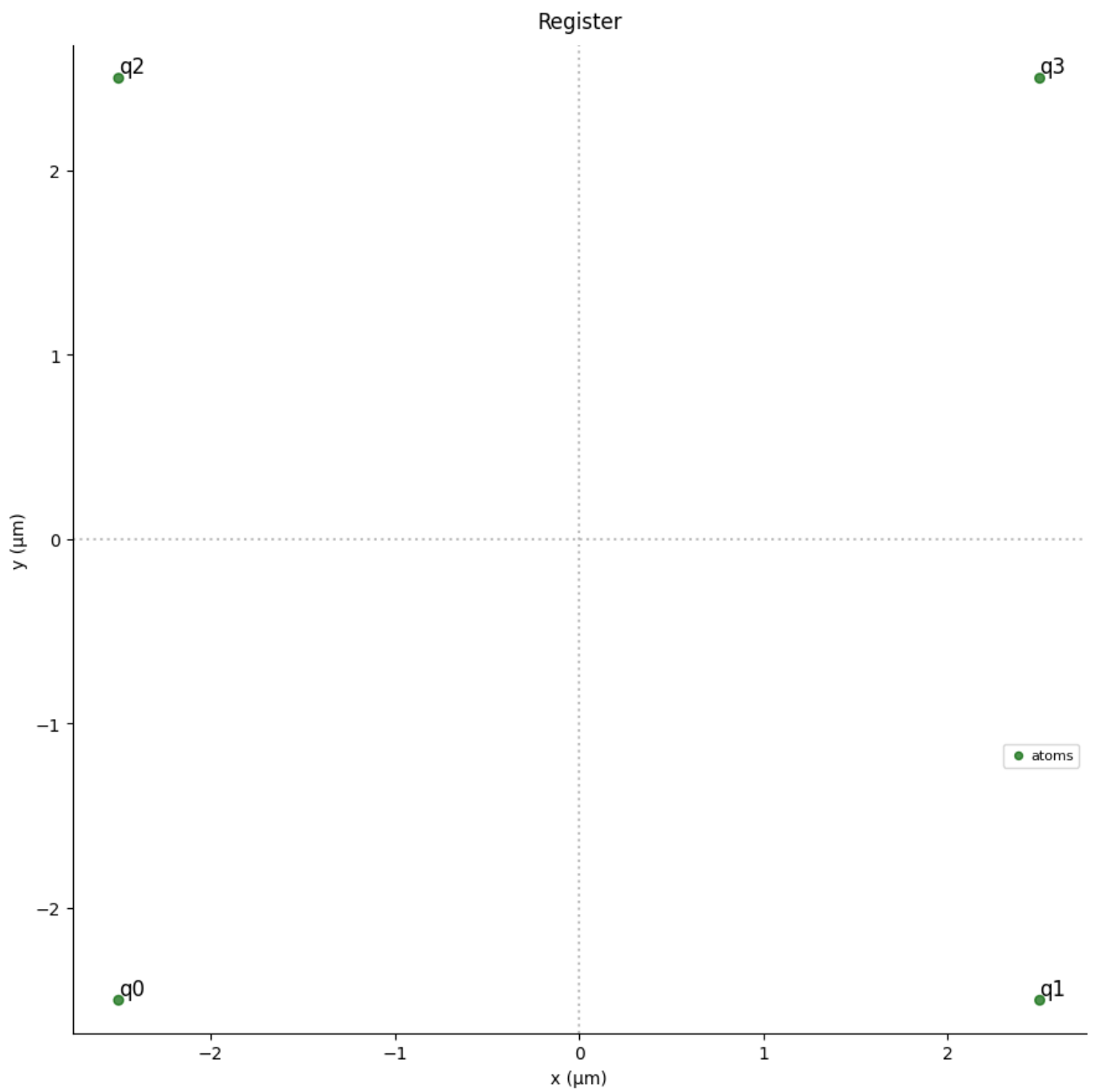
```
In [1]: import pulser
import pulser_simulation
import numpy as np
import qutip
```

```
In [2]: pulser.AnalogDevice.to_abstract_repr()
```

```
Out[2]: '{"name": "AnalogDevice", "dimensions": 2, "rydberg_level": 60, "min_atom_distance": 5, "max_
atom_num": 25, "max_radial_distance": 35, "interaction_coeff_xy": null, "supports_slm_mask":
false, "max_layout_filling": 0.5, "max_sequence_duration": 4000, "max_runs": 2000, "reusable_
channels": false, "pre_calibrated_layouts": [{"coordinates": [[-20.0, 0.0], [-17.5, -4.33012
7], [-17.5, 4.330127], [-15.0, -8.660254], [-15.0, 0.0], [-15.0, 8.660254], [-12.5, -12.99038
1], [-12.5, -4.330127], [-12.5, 4.330127], [-12.5, 12.990381], [-10.0, -17.320508], [-10.0,
-8.660254], [-10.0, 0.0], [-10.0, 8.660254], [-10.0, 17.320508], [-7.5, -12.990381], [-7.5,
-4.330127], [-7.5, 4.330127], [-7.5, 12.990381], [-5.0, -17.320508], [-5.0, -8.660254],
[-5.0, 0.0], [-5.0, 8.660254], [-5.0, 17.320508], [-2.5, -12.990381], [-2.5, -4.330127],
[-2.5, 4.330127], [-2.5, 12.990381], [0.0, -17.320508], [0.0, -8.660254], [0.0, 0.0], [0.0,
8.660254], [0.0, 17.320508], [2.5, -12.990381], [2.5, -4.330127], [2.5, 4.330127], [2.5, 12.9
90381], [5.0, -17.320508], [5.0, -8.660254], [5.0, 0.0], [5.0, 8.660254], [5.0, 17.320508],
[7.5, -12.990381], [7.5, -4.330127], [7.5, 4.330127], [7.5, 12.990381], [10.0, -17.320508],
[10.0, -8.660254], [10.0, 0.0], [10.0, 8.660254], [10.0, 17.320508], [12.5, -12.990381], [1
2.5, -4.330127], [12.5, 4.330127], [12.5, 12.990381], [15.0, -8.660254], [15.0, 0.0], [15.0,
8.660254], [17.5, -4.330127], [17.5, 4.330127], [20.0, 0.0]], "slug": "TriangularLatticeLayou
t(61, 5.0\u00b5m)"}], "accepts_new_layouts": false, "version": "1", "pulser_version": "1.2de
v1", "channels": [{"id": "rydberg_global", "basis": "ground-rydberg", "addressing": "Global",
"max_abs_detuning": 125.66370614359172, "max_amp": 12.566370614359172, "min_retarget_interval
": null, "fixed_retarget_t": null, "max_targets": null, "clock_period": 4, "min_duration": 16
, "max_duration": 100000000, "mod_bandwidth": 8, "eom_config": {"limiting_beam": "RED", "max_
limiting_amp": 188.49555921538757, "intermediate_detuning": 2827.4333882308138, "controlled_b
eams": ["BLUE"], "mod_bandwidth": 40, "custom_buffer_time": 240}}, "is_virtual": false}'
```

```
In [3]: seq = pulser.Sequence(pulser.Register.square(2, 5, "q"), pulser.AnalogDevice)
seq.declare_channel("ising", "rydberg_global")
seq.add(pulser.Pulse.ConstantPulse(1000, np.pi/2, 0, 0), "ising")
seq.delay(100, "ising")
seq.add(pulser.Pulse(pulser.BlackmanWaveform(1000, np.pi/2), pulser.RampWaveform(1000, -np.pi,
```

```
In [4]: seq.draw(draw_register=True)
```



```
In [5]: backend = pulser_simulation.QutipBackend(seq)
```

```
In [6]: import qutip
```

```
In [7]: backend._sim_obj._hamiltonian._hamiltonian(θ)
```

Out[7]: Quantum object: dims=[[2, 2, 2, 2], [2, 2, 2, 2]], shape=(16, 16), type='oper', dtype=CSR, isherm=True

$$\begin{pmatrix} 235.477 & 0.785 & 0.785 & 0 & 0.785 & \dots & 0 & 0 & 0 & 0 & 0 \\ 0.785 & 117.738 & 0 & 0.785 & 0 & \dots & 0 & 0 & 0 & 0 & 0 \\ 0.785 & 0 & 117.738 & 0.785 & 0 & \dots & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.785 & 0.785 & 55.406 & 0 & \dots & 0.785 & 0 & 0 & 0 & 0 \\ 0.785 & 0 & 0 & 0 & 117.738 & \dots & 0 & 0.785 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0.785 & 0 & \dots & 0 & 0 & 0 & 0 & 0.785 \\ 0 & 0 & 0 & 0 & 0.785 & \dots & 0 & 55.406 & 0.785 & 0.785 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0.785 & 0 & 0 & 0.785 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0.785 & 0 & 0 & 0.785 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0.785 & 0 & 0.785 & 0.785 & 0 \end{pmatrix}$$

In [8]: `backend._sim_obj._hamiltonian._hamiltonian.copy()`

Out[8]: QobjEvo: dims = [[2, 2, 2, 2], [2, 2, 2, 2]], shape = (16, 16), type = oper, superrep = None, isconstant = False, num\_elements = 4

In [9]: `%timeit backend.run()`

53.1 ms ± 1.85 ms per loop (mean ± std. dev. of 7 runs, 10 loops each)

In [10]: `mod_backend = pulser_simulation.QutipBackend(  
 seq,  
 pulser.EmulatorConfig(  
 with_modulation=True  
 )  
)`

In [11]: `%timeit mod_backend.run()`

58.2 ms ± 4.46 ms per loop (mean ± std. dev. of 7 runs, 10 loops each)

In [12]: `t_backend = pulser_simulation.QutipBackend(  
 seq,  
 pulser.EmulatorConfig(  
 with_modulation=True,  
 noise_model=pulser.NoiseModel(  
 temperature=0.1,  
 runs=10,  
 samples_per_run=1,  
 )  
 )  
)`

In [13]: `%timeit t_backend.run()`

1.64 s ± 61.6 ms per loop (mean ± std. dev. of 7 runs, 1 loop each)

In [14]: `relax_backend = pulser_simulation.QutipBackend(  
 seq,  
 pulser.EmulatorConfig(  
 with_modulation=True,  
 noise_model=pulser.NoiseModel(  
 relaxation_rate=0.1,  
 )  
 )  
)`

In [15]: `relax_backend._sim_obj._hamiltonian._hamiltonian(0)`

Out[15]: Quantum object: dims=[[2, 2, 2, 2], [2, 2, 2, 2]], shape=(16, 16), type='oper', dtype=CSR, isherm=True

$$\begin{pmatrix} 235.477 & 0.004 & 0.004 & 0 & 0.004 & \dots & 0 & 0 & 0 & 0 & 0 \\ 0.004 & 117.738 & 0 & 0.004 & 0 & \dots & 0 & 0 & 0 & 0 & 0 \\ 0.004 & 0 & 117.738 & 0.004 & 0 & \dots & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.004 & 0.004 & 55.406 & 0 & \dots & 0.004 & 0 & 0 & 0 & 0 \\ 0.004 & 0 & 0 & 0 & 117.738 & \dots & 0 & 0.004 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0.004 & 0 & \dots & 0 & 0 & 0 & 0 & 0.004 \\ 0 & 0 & 0 & 0 & 0.004 & \dots & 0 & 55.406 & 0.004 & 0.004 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0.004 & 0 & 0 & 0.004 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0.004 & 0 & 0 & 0.004 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0.004 & 0 & 0.004 & 0.004 & 0 \end{pmatrix}$$

In [16]: `relax_backend._sim_obj._hamiltonian._collapse_ops`





```

0.      0.      0.      0.      0.      0.
[0.      0.      0.      0.      0.      0.
 0.      0.      0.      0.      0.      0.
 0.      0.      0.      0.      ]
[0.      0.      0.      0.      0.      0.
 0.      0.      0.31622777 0.      0.      0.
 0.      0.      0.      0.      ]
[0.      0.      0.      0.      0.      0.
 0.      0.      0.      0.31622777 0.      0.
 0.      0.      0.      0.      ]
[0.      0.      0.      0.      0.      0.
 0.      0.      0.      0.      0.      0.
 0.      0.      0.      0.      ]
[0.      0.      0.      0.      0.      0.
 0.      0.      0.      0.      0.      0.
 0.31622777 0.      0.      0.      ]
[0.      0.      0.      0.      0.      0.
 0.      0.      0.      0.      0.      0.
 0.      0.31622777 0.      0.      ],

```

Quantum object: dims=[[2, 2, 2, 2], [2, 2, 2, 2]], shape=(16, 16), type='oper', dtype=CSR, i  
sherm=False

Qobj data =

```

[[0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      ]
 [0.31622777 0.      0.      0.      0.      0.
  0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      ]
 [0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      ]
 [0.      0.      0.31622777 0.      0.      0.
  0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      ]
 [0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      ]
 [0.      0.      0.      0.      0.31622777 0.
  0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      ]
 [0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      ]
 [0.      0.      0.      0.      0.      0.
  0.31622777 0.      0.      0.      0.      0.
  0.      0.      0.      0.      ]
 [0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      ]
 [0.      0.      0.      0.      0.      0.
  0.      0.      0.31622777 0.      0.      0.
  0.      0.      0.      0.      ]
 [0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      ]
 [0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      0.31622777 0.
  0.      0.      0.      0.      ]
 [0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      ]
 [0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      0.      0.
  0.      0.      0.      0.      ]

```

```

0.31622777 0.      0.      0.      ]
[0.      0.      0.      0.      0.      0.
 0.      0.      0.      0.      0.      0.
 0.      0.      0.      0.      ]
[0.      0.      0.      0.      0.      0.
 0.      0.      0.      0.      0.      0.
 0.      0.      0.31622777 0.      0.      ]]]

```

```
In [17]: %timeit relax_backend.run()
```

113 ms ± 6.53 ms per loop (mean ± std. dev. of 7 runs, 10 loops each)

```
In [18]: qutip.Qobj([[0, 0, 1], [0, 0, 1], [1, 1, 0]])
```

Out[18]: Quantum object: dims=[[3], [3]], shape=(3, 3), type='oper', dtype=Dense, isherm=True

$$\begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 1 \\ 1 & 1 & 0 \end{pmatrix}$$

```
In [19]: leakage_backend = pulser_simulation.QutipBackend(
    seq,
    pulser.EmulatorConfig(
        with_modulation=True,
        noise_model=pulser.NoiseModel(
            with_leakage=True,
            eff_noise_ops=[qutip.Qobj([[0, 0, 1], [0, 0, 1], [1, 1, 0]])],
            eff_noise_rates=[0.1]
        )
    )
)
```

```
[[0.+0.j 0.+0.j 1.+0.j]
 [0.+0.j 0.+0.j 1.+0.j]
 [1.+0.j 1.+0.j 0.+0.j]]
```

```
In [20]: leakage_backend._sim_obj._hamiltonian._hamiltonian(0)
```

Out[20]: Quantum object: dims=[[3, 3, 3, 3], [3, 3, 3, 3]], shape=(81, 81), type='oper', dtype=CSR, isherm=True

$$\begin{pmatrix} 235.477 & 0.004 & 0 & 0.004 & 0 & \dots & 0 & 0 & 0 & 0 & 0 \\ 0.004 & 117.738 & 0 & 0 & 0.004 & \dots & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 117.738 & 0 & 0 & \dots & 0 & 0 & 0 & 0 & 0 \\ 0.004 & 0 & 0 & 117.738 & 0.004 & \dots & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.004 & 0 & 0.004 & 55.406 & \dots & 0 & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0.004 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0.004 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

```
In [21]: leakage_backend._sim_obj._hamiltonian._collapse_ops
```



```

Out[21]: [Quantum object: dims=[[3, 3, 3, 3], [3, 3, 3, 3]], shape=(81, 81), type='oper', dtype=CSR, i
sherm=True
Qobj data =
[[0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]
 ...
 [0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]],
Quantum object: dims=[[3, 3, 3, 3], [3, 3, 3, 3]], shape=(81, 81), type='oper', dtype=CSR, i
sherm=True
Qobj data =
[[0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]
 ...
 [0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]],
Quantum object: dims=[[3, 3, 3, 3], [3, 3, 3, 3]], shape=(81, 81), type='oper', dtype=CSR, i
sherm=True
Qobj data =
[[0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]
 ...
 [0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]
 [0. 0. 0. ... 0. 0. 0.]],
Quantum object: dims=[[3, 3, 3, 3], [3, 3, 3, 3]], shape=(81, 81), type='oper', dtype=CSR, i
sherm=True
Qobj data =
[[0.          0.          0.31622777 ... 0.          0.          0.          ]
 [0.          0.          0.31622777 ... 0.          0.          0.          ]
 [0.31622777 0.31622777 0.          ... 0.          0.          0.          ]
 ...
 [0.          0.          0.          ... 0.          0.          0.31622777]
 [0.          0.          0.          ... 0.          0.          0.31622777]
 [0.          0.          0.          ... 0.31622777 0.31622777 0.          ]]]

```

```
In [22]: %timeit leakage_backend.run()
```

1.21 s ± 28 ms per loop (mean ± std. dev. of 7 runs, 1 loop each)