Building the Hamiltonian

In[∘]:=
```
bsize = 20; ω0 = 1.0;
(*Two level system initial Hamiltonian*)
H0TSS = SparseArray[Band[{1, 1}] → {-ω0/2, ω0/2}];
(*QHO Hamiltonian*)
H0HO = SparseArray[Band[{1, 1}] → Table[n + 1/2, {n, 0, bsize - 1}]];
σp = {{0, 0}, {1, 0}};
σm = {{0, 1}, {0, 0}};

(*Annihilation operator definition*)
a = SparseArray[Band[{1, 2}] → Table[Sqrt[n], {n, 1, bsize - 1}], {bsize, bsize}];

(*We have to choose a convention, i.e.,
the TSS is on the left in tensor producs, while the HO is on the right*)
H0 = KroneckerProduct[IdentityMatrix[2], H0HO] +
   KroneckerProduct[H0TSS, IdentityMatrix[bsize]];
(* Scaling via tensor product *)

(*The coupling terms*)
Hcoup = 0.1 (KroneckerProduct[σp, a] + KroneckerProduct[σm, a†]);
(*Hamiltonian for JC model with RWA made*)
γ = 0.005;
Decay = - I * γ * a† .a;
Hdecay = KroneckerProduct[IdentityMatrix[2], Decay];
Htot = H0 + Hcoup + Hdecay;
```

Initial state

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ψ0[w_, x0_] = 1/(Sqrt[Sqrt[π] w]) Exp[-(x - x0)^2/(2 w^2)];(*Define initial Gaussian state*)
EigState[n_, x_] = π^(-1/4)/(Sqrt[2^n n!]) Exp[-x^2/2] HermiteH[n, x];
coeff[n_, w_, x0_] := NIntegrate[EigState[n, x] × ψ0[w, x0],
  {x, -∞, ∞}, PrecisionGoal → 6, AccuracyGoal → 5]
ψ0HO = Table[coeff[n, 1, 2], {n, 0, bsize - 1}];

(*excited state in TSS and Gaussian in the QHO*)
ψ0Vec = KroneckerProduct[{0, 1}, ψ0HO] // Flatten;
```

Build observable matrices

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xM = KroneckerProduct[IdentityMatrix[2], 1/Sqrt[2] (a† + a)];
(*Position of the oscillator*)
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Test the observable matrix

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(*Expected x value for initial state*)
ConjugateTranspose[ψ0Vec].xM.ψ0Vec
xMSquared = xM . xM;
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Propagate Initial State (position basis)

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(* Define the time-evolved state vector *)
timeEvolutionOperator[t_] := MatrixExp[-I * Htot * t];
stateVector[t_] := timeEvolutionOperator[t] . ψ0Vec;

(* Compute expectation values *)
expectationValueX[t_] := ConjugateTranspose[stateVector[t]].xM.stateVector[t];
expectationValueXSquared[t_] :=
  ConjugateTranspose[stateVector[t]].xMSquared.stateVector[t];

(*Tensor product with the QHO identity to get appropriately scaled operators*)
iqho = IdentityMatrix[bsize];
P1 = {{0, 0}, {0, 1}}; (*Excited state projection operator*)
P1full = KroneckerProduct[P1, iqho];
populationExcited[t_] :=
  ConjugateTranspose[stateVector[t]].P1full.stateVector[t];

tMax = 400;

avgPositionPlotQHO = Plot[Re[expectationValueX[t]],
    {t, 0, tMax}, PlotLabel → "Average Position <x>",
    AxesLabel → {"Time", "<x>"}, PlotRange → Full];
avgStatePlotTSS =
 Plot[{Re[populationExcited[t]]}, {t, 0, tMax}, PlotLegends → {"Excited State"},
  AxesLabel → {"Time", "Population"}, PlotRange → {0, 1}, PlotStyle → Red]

Show[avgPositionPlotQHO, PlotRange → All, ImageSize → Large]
```

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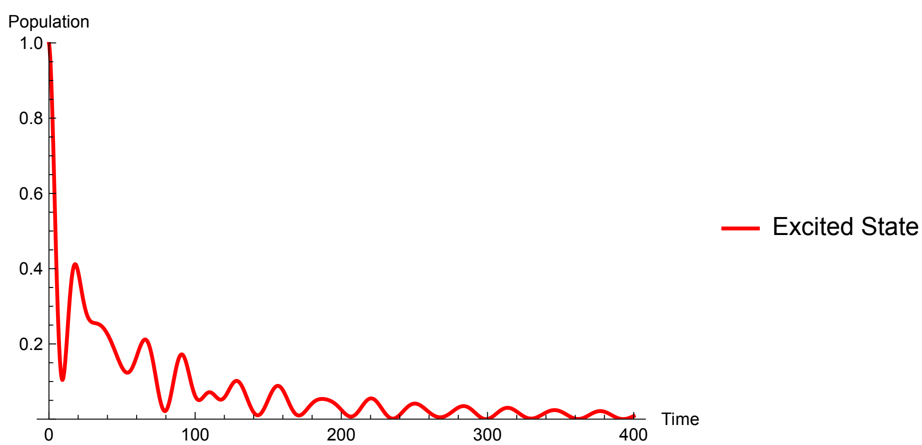

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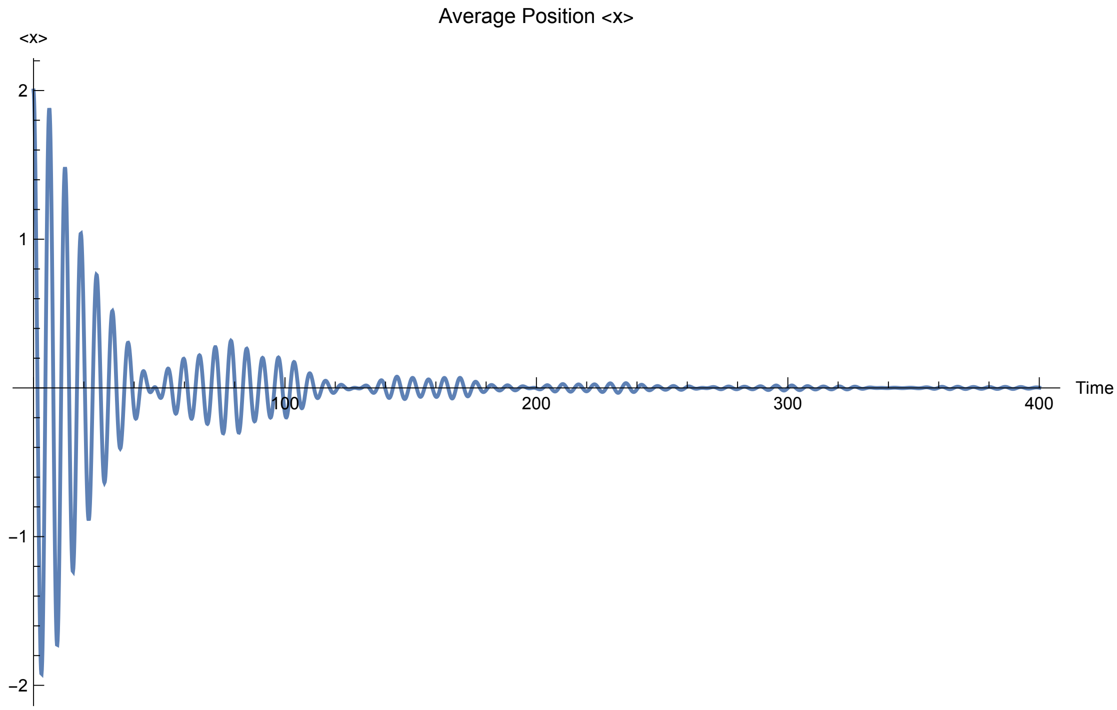

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