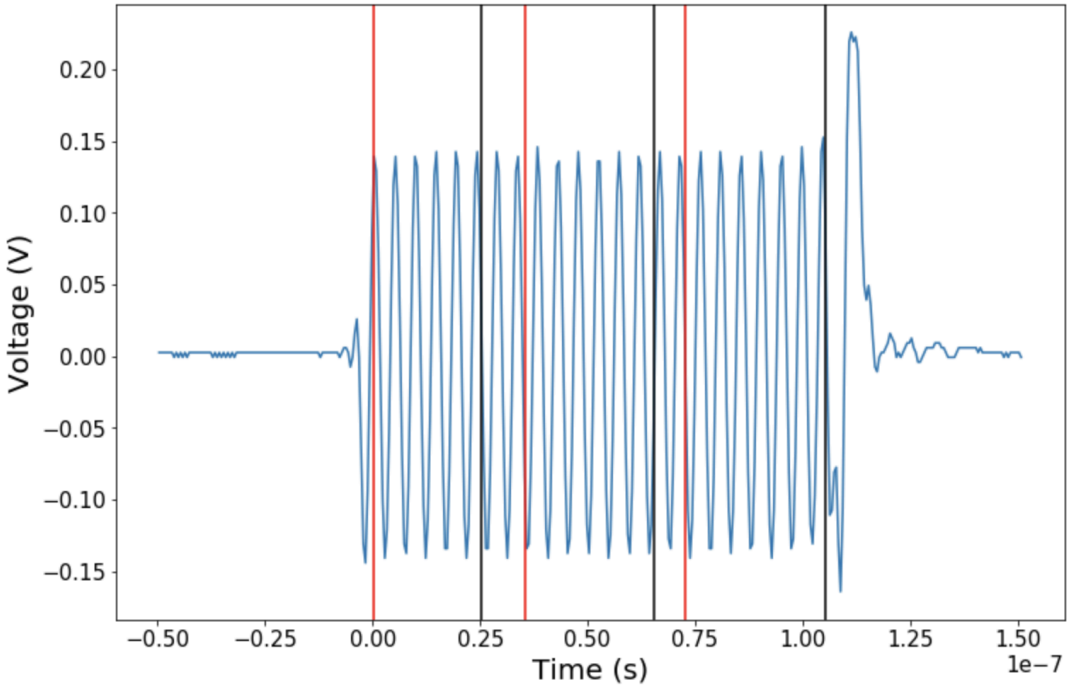
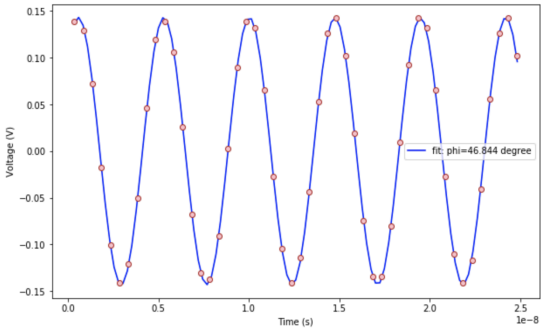
01/04 Phase tracking waveform

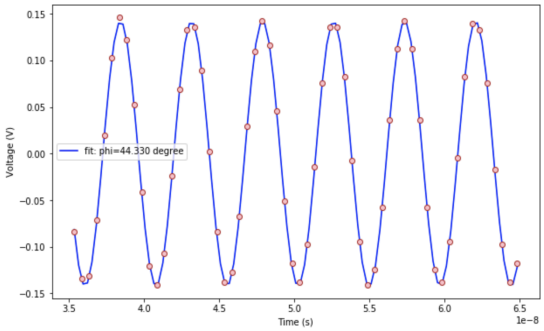
Thursday, January 4, 2024 7:04 PM

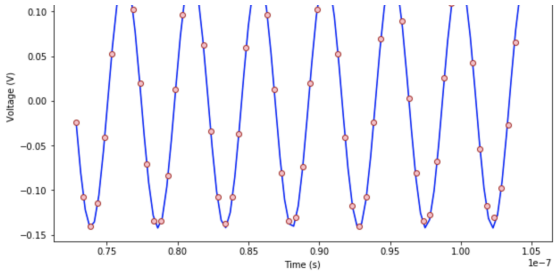
1. Single frequency, change phases in between
   Circuit:
   Sync, freq = 200MHz, 50ns, phi =90 ->
   Sync, freq = 200MHz, 50ns, phi =90 ->
   Sync, freq = 200MHz, 50ns, phi =90



Sin(w t + phi)

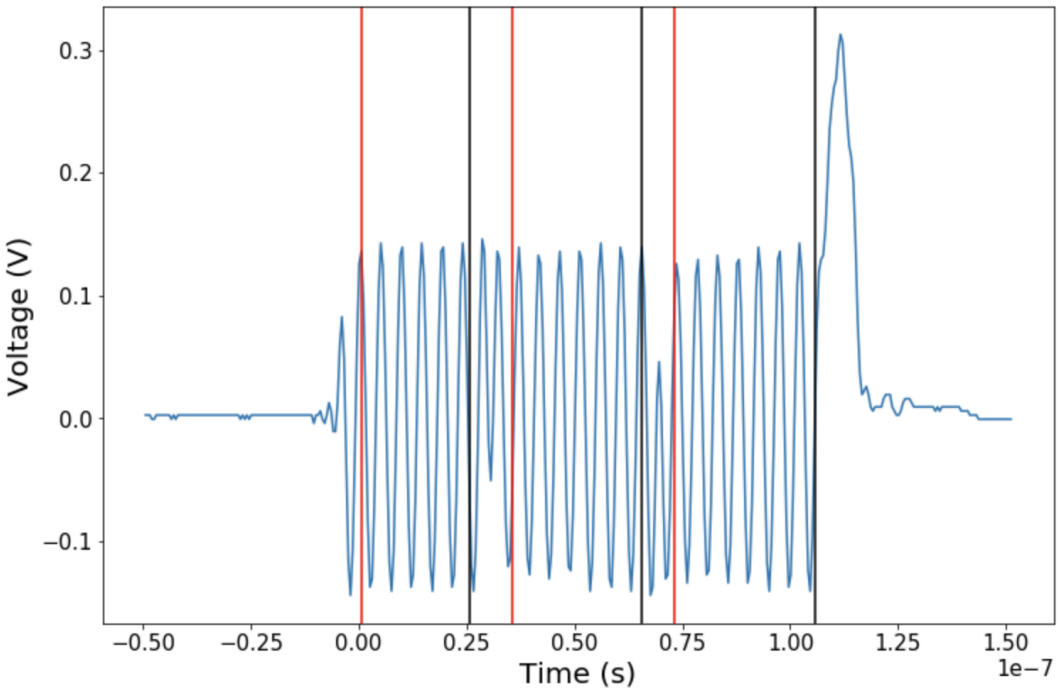






Fitted phases are `46.844, 44.330, 44.061` degree, the differences in between are `-2.514, -0.269` degree

Circuit:
Sync, freq = 200MHz, 50ns, phi =0 ->
Sync, freq = 200MHz, 50ns, phi =90 ->
Sync, freq = 200MHz, 50ns, phi =180



Fitted phases are `51.511, 141.256, 230.892` degree, the differences in between are `89.745, 89.636` degree

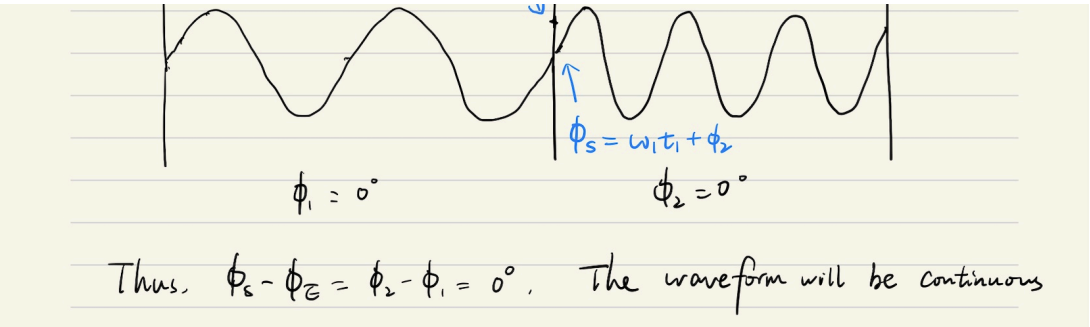
2. Multiple frequencies, change phases in between

How the phase tracker works is as follows:
① Record the phase that the signal has evolved: $\Delta\phi = \omega \cdot t$.
② Use the lookup table to add a phase offset ϕ_0 to the pulse, where ϕ_0 is the phase we set in the software.

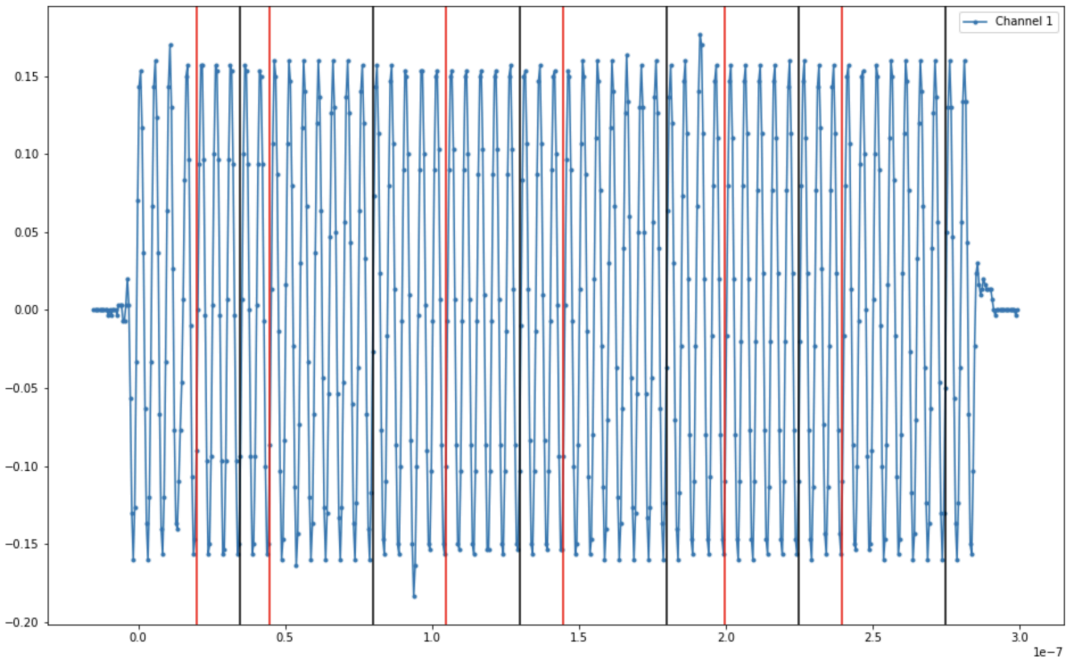
Thus, the phase of the signal is $\phi = \omega t + \phi_0$. We can SET ϕ_0 as the spin and motion phase as we want.

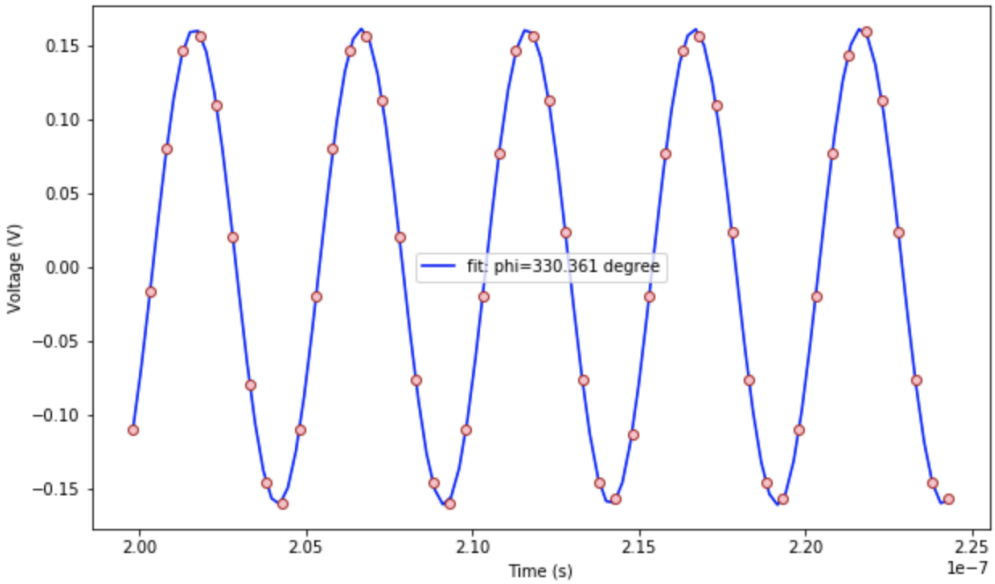
Eg. 1. Pulse 1, ω_1, t_1, ϕ_1 Pulse 2, ω_2, t_2, ϕ_2

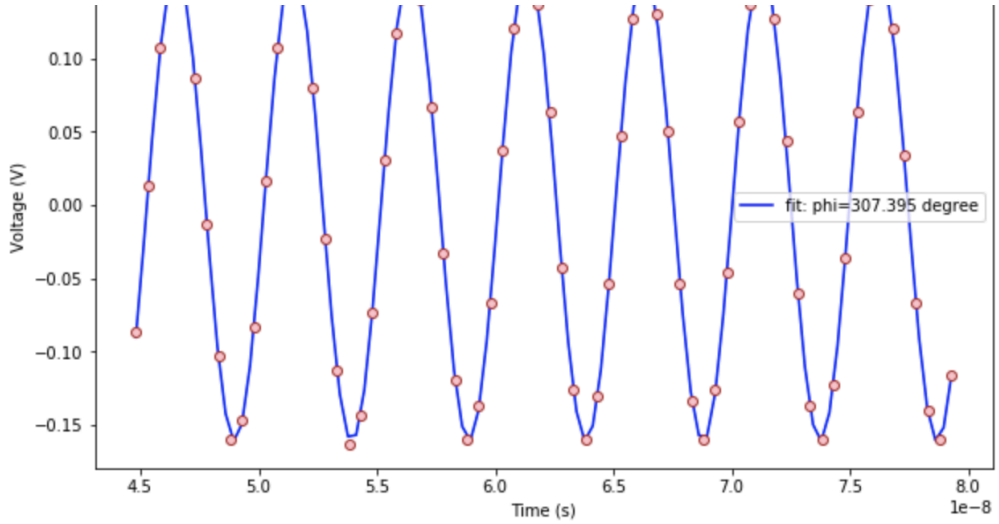
$\phi_E = \omega_1 t_1 + \phi_1$



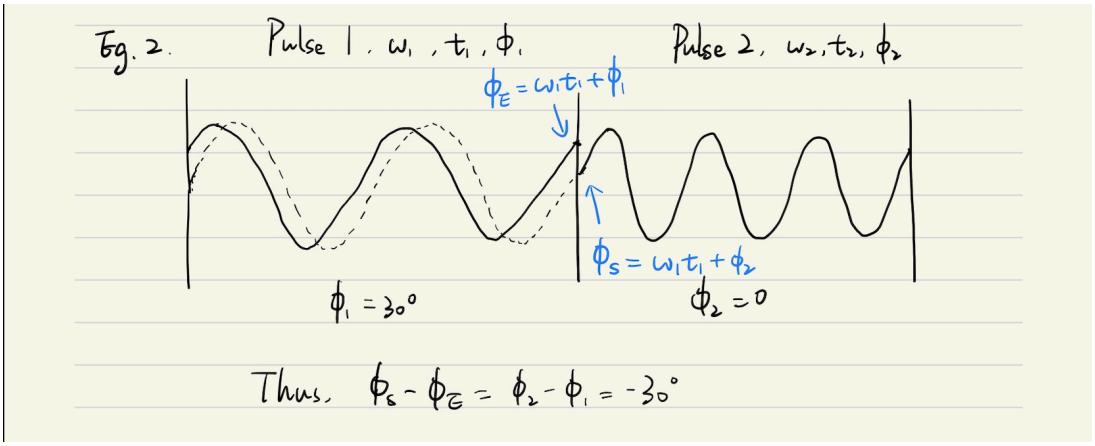
Circuit:
Sync, freq = 200MHz, 50ns, phi =0 -> No Sync, freq = 202MHz, 50ns, phi =0 ->
Sync, freq = 200MHz, 50ns, phi =0 -> No Sync, freq = 202MHz, 50ns, phi =0 ->
Sync, freq = 200MHz, 50ns, phi =0 -> No Sync, freq = 202MHz, 50ns, phi =0 ->








```
Fitted phases:  [338.57227271 307.39468282 334.54681977 232.73980022 330.36068264
 158.25874956]
First Trotter step:
phase_end =  3938.5722727089405
phase_start =  3943.394682824706
phase_start -  phase_end=  4.822410115765251


Second Trotter step:
phase_end =  11134.546819774732
phase_start =  11140.739800223651
phase_start -  phase_end=  6.192980448919116


Third Trotter step:
phase_end =  18330.360682643008
phase_start =  18338.258749564193
phase_start -  phase_end=  7.898066921185091
```

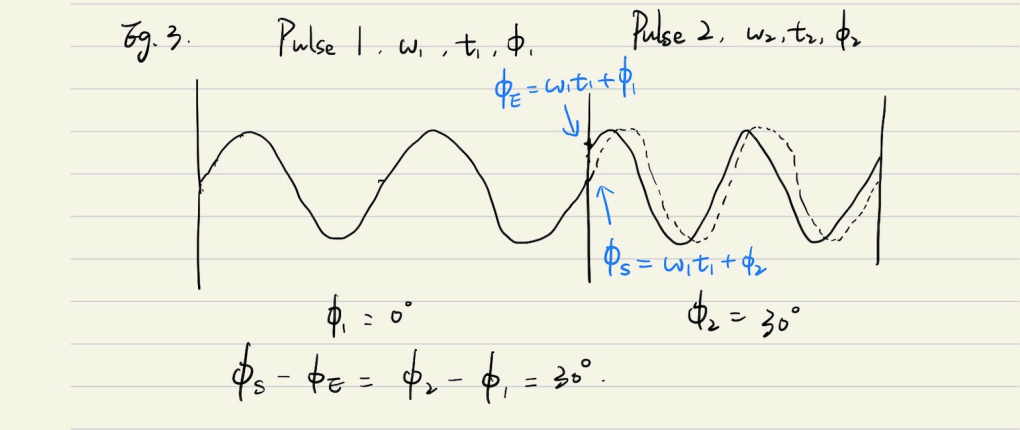


Circuit:

Sync, freq = 200MHz, 50ns, phi =0 -> No Sync, freq = 202MHz, 50ns, phi =0 ->
Sync, freq = 200MHz, 50ns, phi =30 -> No Sync, freq = 202MHz, 50ns, phi =0 ->
Sync, freq = 200MHz, 50ns, phi =60 -> No Sync, freq = 202MHz, 50ns, phi =0

```
Fitted phases:  [137.53097004 101.33975081 162.55042161  26.11086407 187.55724566
 310.68446395]
First Trotter step:
phase_end =  3737.530970035013
phase_start =  3737.3397508103535
phase_start -  phase_end=  -0.19121922465956231


Second Trotter step:
phase_end =  10962.550421607437
phase_start =  10934.110864068878
```

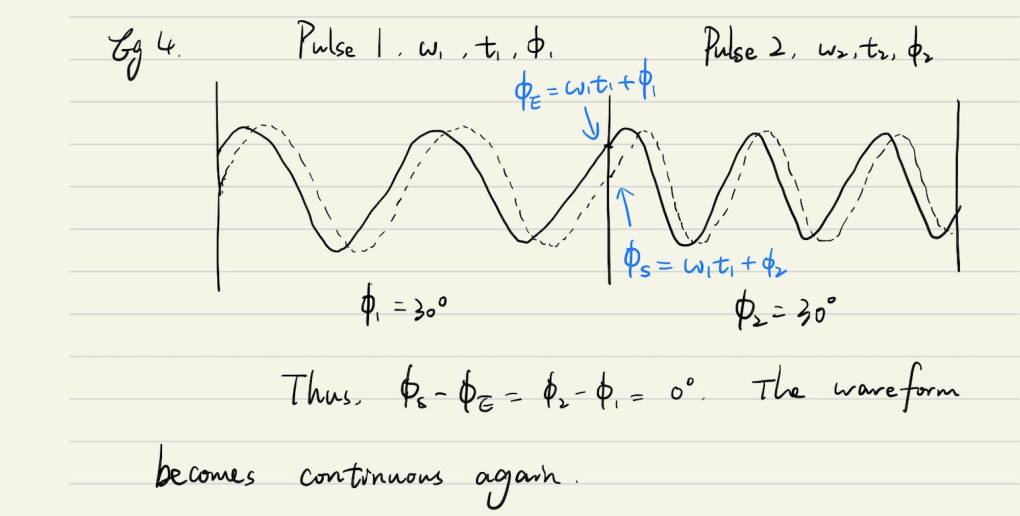
```
phase_start -  phase_end=  -28.439557385588


Third Trotter step:
phase_end =  18187.55724566196
phase_start =  18130.68446395226
phase_start -  phase_end=  -56.87278170969876
```



Circuit:

Sync, freq = 200MHz, 50ns, phi =0 -> No Sync, freq = 202MHz, 50ns, phi =0 -> Sync, freq = 200MHz, 50ns, phi =0 -> No Sync, freq = 202MHz, 50ns, phi =30 -> Sync, freq = 200MHz, 50ns, phi =0 -> No Sync, freq = 202MHz, 50ns, phi =60

```
Fitted phases:  [198.84517429 161.06471864 192.94339966 114.42177264 187.03766635
  68.02313343]
First Trotter step:
phase_end =  3798.8451742891375
phase_start =  3797.0647186425495
phase_start -  phase_end=  -1.7804556465880523


Second Trotter step:
phase_end =  10992.943399658723
phase_start =  11022.421772641721
phase_start -  phase_end=  29.478372982997826


Third Trotter step:
phase_end =  18187.037666351778
phase_start =  18248.02313342676
phase_start -  phase_end=  60.98546707498099
```



Circuit:

Sync, freq = 200MHz, 50ns, phi =0 -> No Sync, freq = 202MHz, 50ns, phi =0 ->

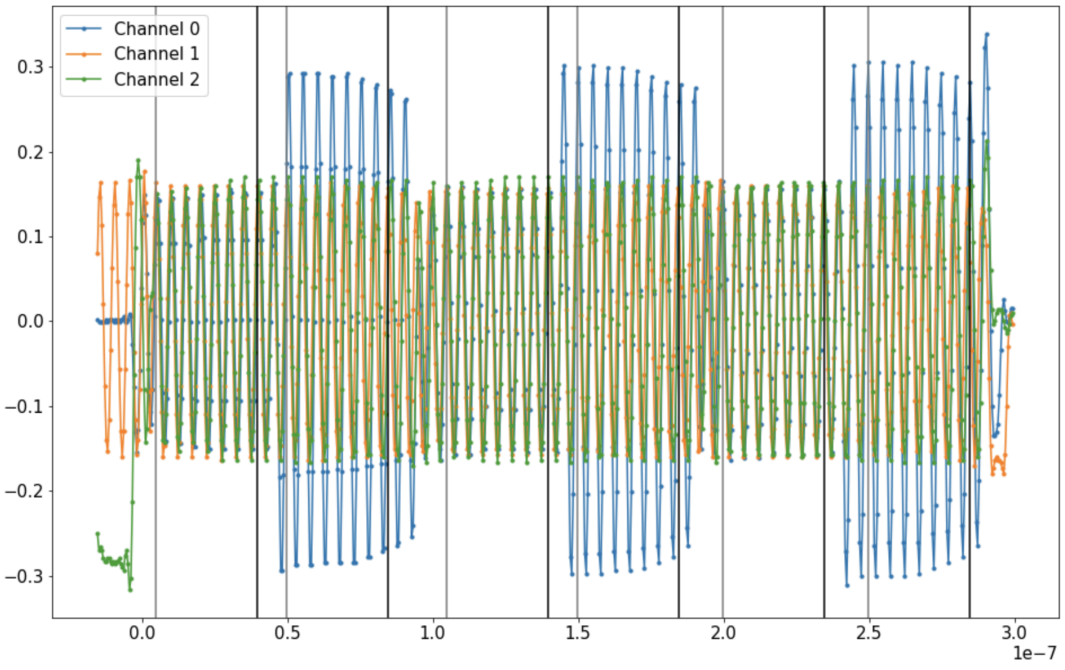
Sync, freq = 200MHz, 50ns, phi =30 -> No Sync, freq = 202MHz, 50ns, phi =30 ->
Sync, freq = 200MHz, 50ns, phi =60 -> No Sync, freq = 202MHz, 50ns, phi =60

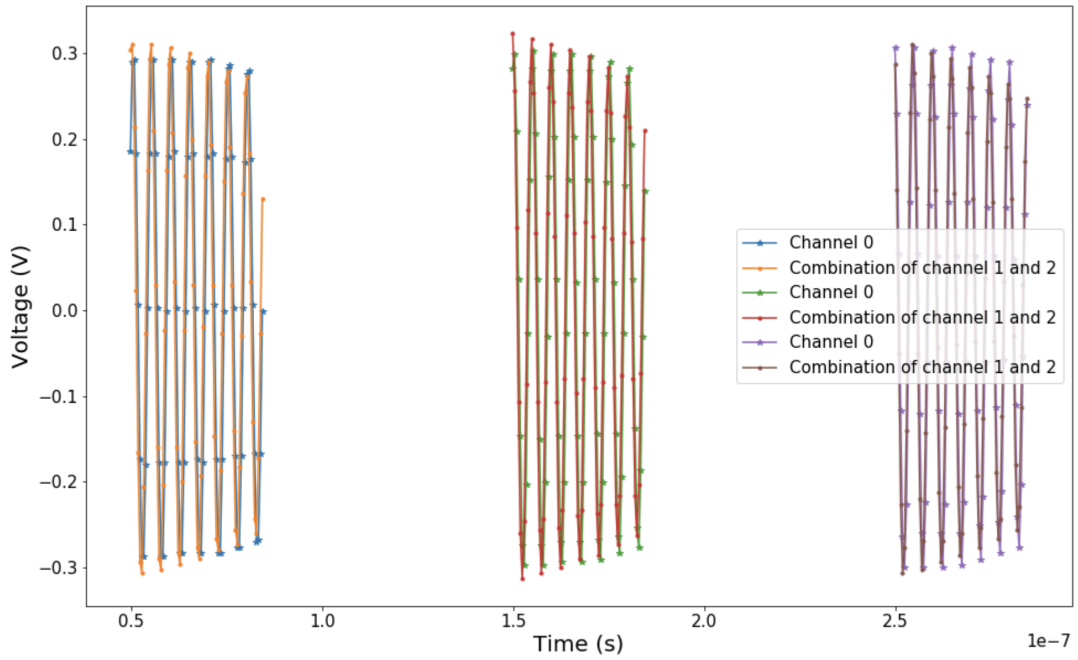
```
Fitted phases:  [ 93.40316932  56.88893444 118.67323552  11.41317892 143.85716838
 326.17621939]
First Trotter step:
phase_end =  3693.403169321763
phase_start =  3692.8889344376157
phase_start -  phase_end=  -0.5142348841472995


Second Trotter step:
phase_end =  10918.673235521066
phase_start =  10919.41317892206
phase_start -  phase_end=  0.7399434009930701


Third Trotter step:
phase_end =  18143.857168376453
phase_start =  18146.17621939254
phase_start -  phase_end=  2.319051016085723
```

3. Double frequencies, two tones

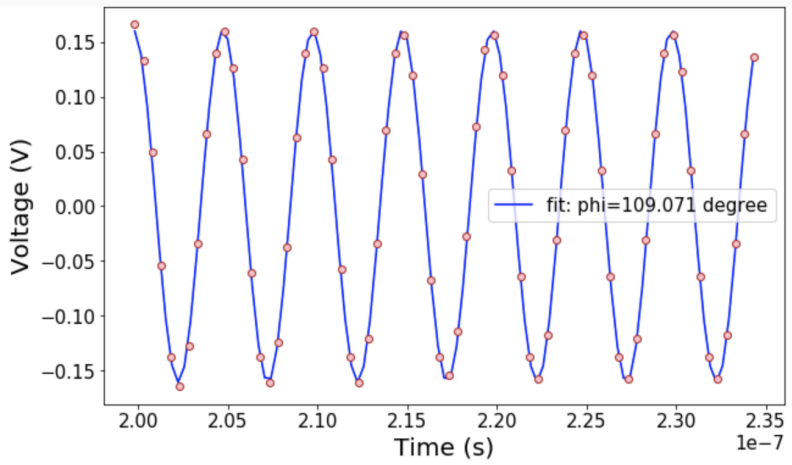
		Pulse 1	Pulse 2
Channel 0	Tone 0	200MHz (amp=30), 50ns	202MHz (amp=30), 50ns
	Tone 1	200MHz (amp=0), 50ns	198MHz (amp=30), 50ns
Channel 1	Tone 0	200MHz (amp=50), 50ns	202MHz (amp=50), 50ns
	Tone 1		
Channel 2	Tone 0	200MHz (amp=30), 50ns	198MHz (amp=30), 50ns
	Tone 1		

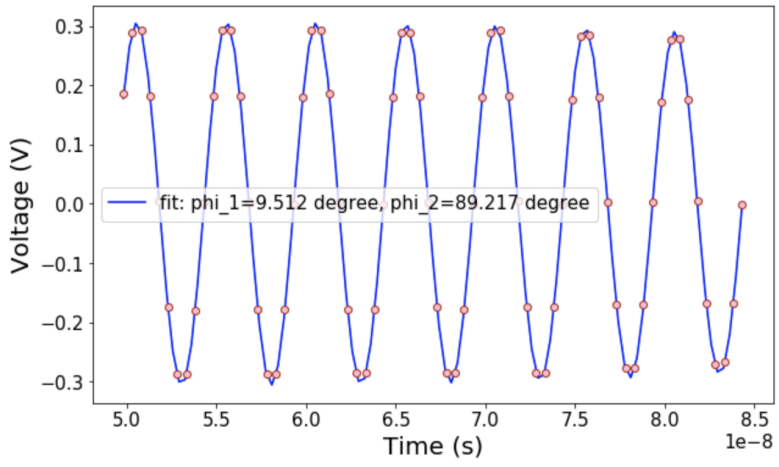
Eg.	Pulse 1	Pulse 2
①	Sync, $\phi = 0°$	No sync, $\phi_r = \phi_b = 0°$
②	Sync, $\phi = 30° \cdot i$	No sync, $\phi_r = \phi_b = 0°$
③	Sync, $\phi = 0°$	No sync, $\phi_r = \phi_b = 30° \cdot i$
④	Sync, $\phi = 30° \cdot i$	No sync, $\phi_r = \phi_b = 30° \cdot i$






```
def func0(t, A, phi_degree):
    return A*np.sin(200e6*t*2*np.pi+phi_degree/180*np.pi)
def func1(t, A, phi_degree):
    return A*np.sin(202e6*t*2*np.pi+phi_degree/180*np.pi)
def func2(t, A, phi_degree):
    return A*np.sin(198e6*t*2*np.pi+phi_degree/180*np.pi)
def func22(t, A, phi_degree_1, phi_degree_2):
    return A*np.sin(202e6*t*2*np.pi+phi_degree_1/180*np.pi)+A*np.sin(198e6*t*2*np.pi+phi_degree_2/180*np.pi)
```





```
diff_r = (np.array(phi_r_ls_1) - np.array(phi_r_ls_2))%360
diff_b = (np.array(phi_b_ls_1) - np.array(phi_b_ls_2))%360
print('Phase difference of red tone is: ', diff_r)
print('Phase difference of blue tone is: ', diff_b)
tone1_r = (diff_r[0]+diff_r[2]+diff_r[4])/3
tone2_r = (diff_r[1]+diff_r[3]+diff_r[5])/3
tone1_b = (diff_b[0]+diff_b[2]+diff_b[4])/3
tone2_b = (diff_b[1]+diff_b[3]+diff_b[5])/3
print('Phase jump of red tone is: ', tone2_r - tone1_r)
print('Phase jump of blue tone is: ', tone2_b - tone1_b)
```

```
Phase difference of red tone is:  [316.11594811 312.62279844 320.98161172 318.09177086 325.21390439
 323.18785616]
Phase difference of blue tone is:  [335.58390278 343.42719121 343.49660076 348.15377354 347.88783647
 353.19738152]
Phase jump of red tone is:  -2.8030129177844856
Phase jump of blue tone is:  5.936668755602852
```

Evidence:

1. The signal from channel 0 is at the same (?) phase of channel 1+2.
2. We have already checked the phase of channel 1 and channel 2, whey are as expected.

Conclusion:

1. When jumping from 1-tone to 2-tone operation, the phases are working as expected.
2. I didn't see significant phase jump from 1-tone to 2-tone. So the phase jump may come from individual beam?

4. Phase jump

   When adding 30 degree in each Trotter step

   1. Channel 0 (Global (bsb/rsb)):
      i. Phase = [49.51911743, 79.65484725, 109.07107277]
      ii. Interval: 30 degree
   2. Channel 1 (Ind 1):
      i. Phase = [93.40316932, 118.67323552, 143.85716838]
      ii. Interval: 25 degree
   3. Channel 2 (Ind 2):
      i. Phase = [73.93521464, 96.15824649, 121.1832363]
      ii. Interval: 24 degree