



Abstract

The Android application TAPAs, the Toolkit for Accelerator Physics on Androids, was released in 2012 and has over 300 users. TAPAs provides more than 50 calculations, many of which are coupled together. Updates are released about once a month. Calculations for electron storage rings are a particular emphasis, and have expanded to include CSR threshold, ion trapping, Laslett tune shift, emittance dilution, and undulator brightness curves. Other additions include helical superconducting undulators, rf cavity properties, Compton backscattering, and temperature calculations for mixing water.

1. INTRODUCTION

Physicists and engineers need the ability to "back of the envelope" calculations

- Quickly determine if an idea is feasible
- Answer questions during discussions and meetings
- Get rough answer before committing to full-blown calculation

The TAPAs app was developed to address such needs.

2. FEATURES AND CAPABILITIES

2.1 WHY IS THIS A "TOOLKIT"?

Often the calculations within a topic will share certain input values (e.g., the beam energy), so that changing it one calculation will change it in the others. In addition, computed values from one calculation are often shared with other calculations. This allows using the calculations in a coordinated fashion, which is why we used the word "toolkit" in the name. 2.2 HIGHLIGHTS OF CALCULATIONS **Electron Storage Rings** Storage ring scaling with size, energy Longitudinal dynamics, with and without harmonic cavity Beam loading and rf generator parameters Harmonic number optimization Parastic-mode beam loading Top-up Swap-out Gas scattering lifetime Quantum lifetime CSR threshold Ion trapping Crab cavities for short pulses Space-charge tune shift Emittance dilution Resonance diagram New since the last publication is the ability to read lattice data from a file prepared from elegant output. **Free Electron Laser** One-dimensional equations Ming Xie's parametrization Undulators Planar hybrid permanent magnet model Planar superconducting model Helical superconducting model Orbit effects Optical effects Aperture transformations

Synchrotron Radiation	
Source type	Calculations
Bending magnet	Critical energy, critical wavelength, power Plots of flux and angular distribution
Wiggler	Critical energy, critical wavelength, power Plots of flux
Undulator	Plots of flux density, central-cone flux power density, total power, brightness,
Compton backscattering	coherent flux, and coherent fraction Energy, wavelength, photon flux, pulse energy, power

Electron Linac Bunch compression w/ chicane Bunch compression w/ alpha magnet Energy gain and power for SLAC structures Energy loss and spread from CSR Charge, current, and beam power

Recent improvements to TAPAs, the Android application for accelerator physics and engineering calculations

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Electromagnetism Cutoff frequency and attenuation for rectangular waveguide Cavity properties (filling time, voltage/power, ...) Skin depth for nonmagnetic materials Pillbox cavity modes Magnetic fields from wires Kilpatrick criterion Pulsed rf heating Bunch form factors

3. EXAMPLES

3.1 MBA STORAGE RING

TAPAS TAPAS: Toolkit for Accelerator Physi... Storage Ring Scaling

Reference Ring	5 5
APS	Load
E APS	7
C APS-Boo132nm	40
C E APS-Boo92nm	1104 2.51368
E APS-U	0.01
F SRF-II	e 2.4888 0.0249
(MAX-IV E	0.0955
PAR_375MeV	2.8191E-4
E)	: 5.3532
F SIRIUS T	9.626
Vertical Damping Time (ms):	9.631
Longitudinal Damping Time (ms):	4.817
Overvoltage:	1.5

Figure 1: Electron storage ring scaling lattice selection.

TAPAS TAPAS: Toolkit for A	Accelerator Physi	
Ion Trapping		
Mode:	LatticeData	
Beam Current (mA):	200	
Number of Bunches:	324	
Circumference (m):	1103.98	
Emittance Ratio:	1	
H. Rms Beam Size (um):	280	
V. Rms Beam Size (um):	30	
Min. Trapped Mass (mp): Frac. Circ. H2 Trapped: Frac. Circ. CH4 Trapped: Frac. Circ. H2O Trapped: Frac. Circ. CO Trapped: Frac. Circ. CO2 Trapped:	0 0 0.1597	

Figure 3: Ion trapping calculation, showing trapping of CO and CO_2 for $\epsilon_u/\epsilon_x = 1$ in APS-U.

TAPAS TAPAS: Toolkit for Accelerator Physi	
Mode	Harmonic Number Optimizer MostDivisors
Beam Energy (GeV):	6
Target Circ. (m):	1103.979
Target Rf Freq. (MHz):	99.9327
Max. Fractional Offset:	0.1
Best Rf Freq. (MHz): Rf Freq. Offset (Hz): Best Circ. (m): Circ. Offset (mm): Harmonic Number: # Divisors: Divisors:	

TAPAS TAPAS: Toolkit	for Accelerator Physi	:
Storage	Ring Scaling	
Reference Ring		
APS-U	Load	
Energy (GeV):	6	_
Cells:	40	
Circumference (m): Emittance (nm):	1103.98 0.06691	
Emittance Ratio:	0.1	
Horizontal Emittance (nm):	0.063	
Vertical Emittance (nm):	0.0063	
Energy spread (%):	0.0955	
Mom. compaction:	5.6597E-5	
En. Loss/Turn (MeV):	2.2676	
Horizontal Damping Time (ms):	12.072	
Vertical Damping Time (ms):	19.487	
Longitudinal Damping Time (ms):	14.063	
Overvoltage:	1.5	

Figure 2: 67-pm APS-U lattice with $\epsilon_y/\epsilon_x = 0.1$

TAPAS TAPAS: Toolkit for Accelerator Physi				
Ion Trapping				
Mode:	LatticeData			
Beam Current (mA):	200			
Number of Bunches:	324			
Circumference (m):	1103.98			
Emittance Ratio:	0.1			
H. Rms Beam Size (um):	n/a			
V. Rms Beam Size (um):	n/a			
Min. Trapped Mass (mp): Frac. Circ. H2 Trapped: Frac. Circ. CH4 Trapped: Frac. Circ. H2O Trapped: Frac. Circ. CO Trapped: Frac. Circ. CO2 Trapped:	64.3775 0 0 0 0 0			

Figure 4: *Ion trapping calcula*tion, showing absence of trapping for $\epsilon_u/\epsilon_x = 0.1$ in APS-U.

TAPAS TAPAS: Toolkit for Accelerator Physi		:
Longitudinal Dynamics in Storage Rings		
Beam Energy (GeV):	6	
Mom. Compact.:	5.6597E-5	
Harmonic Number:	360	
Circumference (m):	1103.98	
En. Loss (MeV/turn):	2.2676	
Rf Voltage (MV):	3.1976	
Bucket HH (%):	5	
Over Voltage: Rev. Freq. (MHz): Rf Freq. (MHz): Sync. Phase (deg): Sync. Tune: Sync. Freq. (Hz):	1.4101 0.2716 97.7603 134.8334 0.0011 299.7533	
Rms En. Spread (%):	0.0955	
Rms Bunch Length (mm): Rms Bunch Duration (ps):		

Figure 6: Computing the natural bunch length for the chosen harmonic number.

Μ M

Bea Bet Ape X, V Mo

H2(CH₂ CO N2

H2

Figure 11: Estimation of maxi*mum K in a 20-mm-period pla*nar SCU.

Figure 5: Choosing a harmonic number for APS-U near 100 MHz to maximize the number of divisors.

TAPAS TAPAS: Toolkit for Accelerator Physi	
Harmonic Cavities in Storage Rings	
Beam Energy (GeV):	6
Mom. Compact.:	5.6597E-5
Main Voltage (MV):	3.2877
Main Harmonic:	360
Circumference (m):	1103.98
En. Loss (MeV/turn):	2.2676
Harmonic Freq. Ratio:	3
Optimal Lengthening	Copy Parastic Cav.
Iterate Parasitic Cav.	
Main Sync. Phase (deg): 129.1101	
Harmonic Voltage Ratio:	0.2273
Harmonic Voltage (kV):	747.1624
Harmonic Phase (deg):	337.705
Rms En. Spread (%):	0.0955
Rms Bunch Length (mm): 50.8562	

Figure 7: Adding an optimized harmonic cavity to lengthen the bunch.

TAPAS TAPAS: Toolkit for Accelerator Physi...

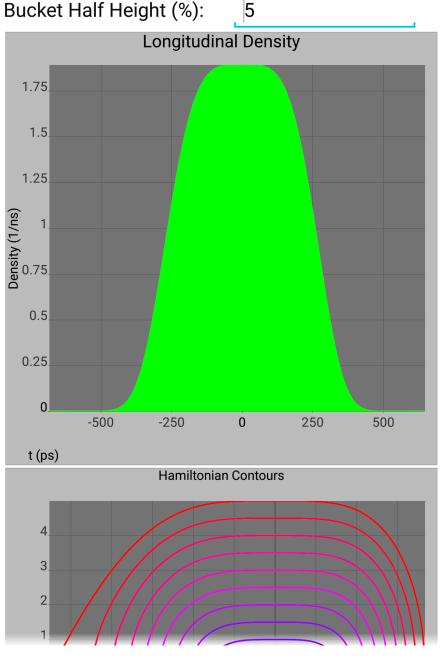


Figure 8: Viewing the bunch length and Hamiltonian contours for a fixed bucket height of $\pm 5\%$.

MASS TAPAS: Toolkit	for Accel	erator Physi	-
Electron Beam Lifetime			
am Energy (GeV):	6	L	
ta x, y Lim. (m):	7	2.6	
erture shape:	Rectang	ular	
' Lim. Ap. (mm):	3.5	1.5	
ta x, y Ave. (m):	4.247	7.82	
om. Accept. (%):	2.5	L	
Pressure (nT):	0.647	L	
0 Pressure (nT):	0.02	L	
4 Pressure (nT):	0.069	L	
Pressure (nT):	0.3	L	
Pressure (nT):	0	L	
2 Pressure (nT):	0.3	L	
al Pressure (nT):	1.3353	L	
mperature (C):	20	L	
etime (h):	43.7521		

Figure 9: Estimation of the gas scattering lifetime for a small dynamic acceptance.

Swap-Out	t Calculations	
Ring:	Calculations	
Current (mA):	200	
Circumference (m):	1103.98	
Harmonic Number:	360	
Bunch Trains:	360	
Bunches/Train:	1	
Lifetime (h):	10	
Inj. Efficiency (%):	90	
Bunch Train Droop (%):	10	
Regulation (% pp): Injector:	0.0264	
Charge/shot (nC): Inj. Interval (s): Inter-Train Gap (buckets	2.3928 10): 1	
Inter-Train Gap (ns): Radiation Load:	10.2291	
Loss Current (pA):	239.2773	
Energy (GeV):	6	
Total Lago Dowar (MA).	1 4057	

TAPAS TAPAS: Toolkit for Accelerator Physi...

Figure 10: Calculation of swap-out parameters for onaxis injection with a 10 hour lifetime.

NbTi Superconducting Undulator		
eriod (mm):	20	
ull mag. gap (mm):	9.5	
Op/Jmax:	0.9	
(T): :	1.3167 2.4589	
nergy (GeV)	6	
h. Energy (keV):	4.2488	
/avelength (A):	2.9181	

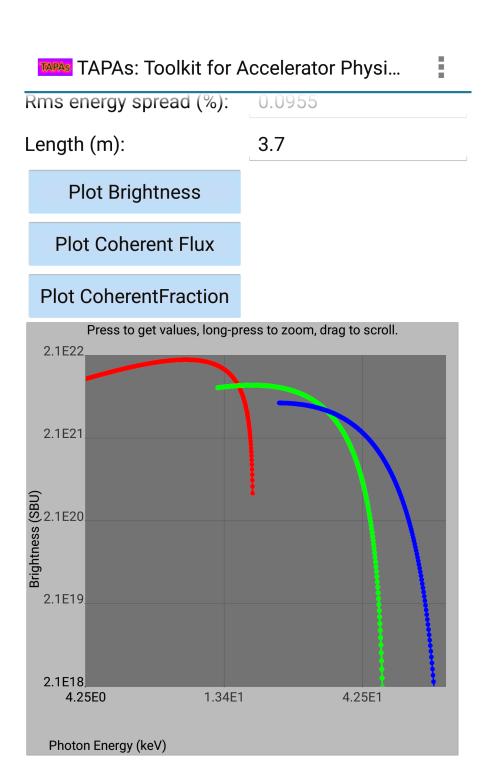


Figure 12: Brightness for 3.7m, 20-mm-period planar SCU in APS-U.

Material Lead

Density (gm/c

Rad. Length (Thickness (cn Critical Energy

Beam Energy Frac. Energy D Frac. Energy T Shower Attenu Shower Maxim

cm of lead.

2
3
ľ
V
l
T
6
_
a
(
e

En. Hor Tim Ver 1 Tim 0 Damping Tim

Overvoltage:

try pad.

The cost- and ad-free TAPAs application for Android devices provides a number of quick, convenient calculations for use in backof-the-envelope estimates and for analysis that would typically be performed with a handbook and calculator. The author hopes that it will prove useful and encourages users to send comments, suggestions, and bug reports to michael.d.borland@gmail.com.





TUPOB61

3.2 OTHER EXAMPLES

Toolkit for Accelerator Physi				
Electromagnetic Shower ased on PPDB section 27.5.				
	82			
	207.2			
cm^3):	11.4			
cm):	0.558746			
n):	8			
y (MeV):	7.3282			
(GeV):	6			
Deposited:	0.9191			
ransmitted:	0.0809			
uation Factor:	12.368			
num (cm):	3.4686			

TAPAs: Toolkit for Accelerator Physi					
Mixing Water Temperature					
Assuming fixed heat capacity, liquid state.					
Check the quantity to compute.					
Temperature 1 (deg):	100				
Mass/Flow/Volume 1: 🥑	0.875				
Temperature 2 (deg):	20				
Mass/Flow/Volume 2:	0.125				
Temperature (deg):	90				
Mass/Flow/Volume:	1				

Figure 13: Attenuation of an electromagnetic shower by 8

Figure 14: Calculation of the amount of boiling and roomtemperature water to combine to make 1 liter of 90° water for green tea.

4. RPN CALCULATOR ENTRY PAD

ator entry pad is provided for number entry, which allows alculation of entries.

rm calculations with values from the activity. w values in full precision.

ent invalid calculations, the calculator interface is sensitive alid return values for the quantity being entered.

Toolkit for Accelerator Physi						
alculator Entry Pad						
E +						
asin	acos	atan	submit			
sin	COS	tan	cancel			
e^x	In	10^x	log			
qrt(x)	1/x	*	/			
8	9	+	-			
5	6	EE	рор			
2	3	enter	swap			
+/-		erase	clear			
e (ms):	15					

Figure 15: Rpn calculator en-

TA	Pick a value	
Ref Al	E:6.0	
Ene	N:40.0	
Cel	q:1.5	
Circ Em_	frf:351.9369802033729	
Em	kappa:0.01	
Ho (nn	C:1103.9789678663715	
Ver (nn	eps0:0.06690783106614129	
Ene Mo	Sdelta0:0.09552475729049152	
En. Hor	alphac:5.659739630953068E-5	
Tim Ver	U0:2.2675962008186223	
Tin Lor	taux:12.07178669586317	
Dar Ove	tauy:19.48747735968374	

Figure 16: Pressing the "Val." button brings up a list of all values in the activity, for use in calculations.

5. CONCLUSIONS