RECENT IMPROVEMENTS TO TAPAS, THE ANDROID APPLICATION FOR ACCELERATOR PHYSICS AND ENGINEERING CALCULATIONS

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Abstract

The Android application TAPAs, the Toolkit for Accelerator Physics on Androids, was released in 2012 and at present has over 300 users. TAPAs provides more than 50 calculations, many of which are coupled together. Updates are released about once a month and have provided many new capabilities. 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.

INTRODUCTION

The need to perform quick, approximate calculations arises frequently in the day-to-day experience of physicists and engineers working at accelerator facilities. This can happen during informal discussions, meetings, reviews, or simply when exploring ideas at one's desk. Being able to perform a reasonably accurate calculation quickly is a great productivity aid in many situations. These days, we are more likely to have a smartphone at hand than almost any other calculation aid. It was with this in mind that the Android application TAPAs [1] was written.

The name TAPAs, "Toolkit for Accelerator Physics for Androids," is meant to bring to mind the popular Spanish cuisine, in that calculations are broken up into many relatively small "activities." The "toolkit" aspect comes into play in that these activities are linked together through sharing of certain numerical inputs and outputs. Figure 1 gives a QR code for downloading TAPAs.

NEW FEATURES AND CAPABILITIES

Calculations within TAPAs are separated into several major categories, namely, Electron Storage Rings, Undulators, Synchrotron Radiation, Electron Linear Accelerators, Electron Guns, Free Electron Lasers, Electromagnetism, Engineering, Particle Passage Through Matter, and APS-Specific Calculations. Most of these have seen improvements and additions since the original publication [1]. One general improvement is that the pop-up calculator used for data entry now consistently includes all input and output quantities under the "Val." button. It is also scrollable, which supports use in split-window mode on Android 7.

Electron Storage Rings

This category has seen perhaps the most changes since the previous publication. One of the most useful activities is the Storage Ring Scaling activity, which allows scaling lattices by the number of cells and beam energy. Several built-in lattices are provided for the convenience of the user, as illustrated in Fig. 2. In addition, TAPAs now allows the user to load custom lattices. To do this, one runs `elegant` [2] for the lattices in question, followed by the script `prepareTAPAs` (distributed with `elegant`). This script prepares a file that can be transferred to one's Android device and then loaded into TAPAs.

Figure 1: QR code for obtaining TAPAs from Google Play.

Several other storage ring activities make use of lattice data as well (regardless of whether it is built-in or user-provided), based on the lattice selected in the scaling activity. Among these are three new activities: ion trapping, Laslett tune shift, and emittance dilution. The ion trapping calculation uses the s-dependent lattice functions, the natural emittance, the energy spread, and the user-specified emittance ratio to compute the fraction of the circumference over which various gas species are expected to be trapped. The functionality is equivalent to that provided by the script `ionTrapping` that is distributed with `elegant`. The Laslett tune shift activity performs integrals over the periodic cell, following [3] and [4]. In both cases, one can perform more approximate calculations even without a lattice by entering values for average beam sizes or lattice functions.

The emittance dilution activity computes transverse and longitudinal emittance dilution due to decoherence following injection of a mismatched, offset beam into a storage ring [5]. In addition, it allows estimation of the time required to damp to within a specified factor of the equilibrium beam properties.

The gas scattering lifetime activity has been improved to support both rectangular and elliptical aperture shapes. The code integrates over the aperture shape in a method similar to that outlined in [6].

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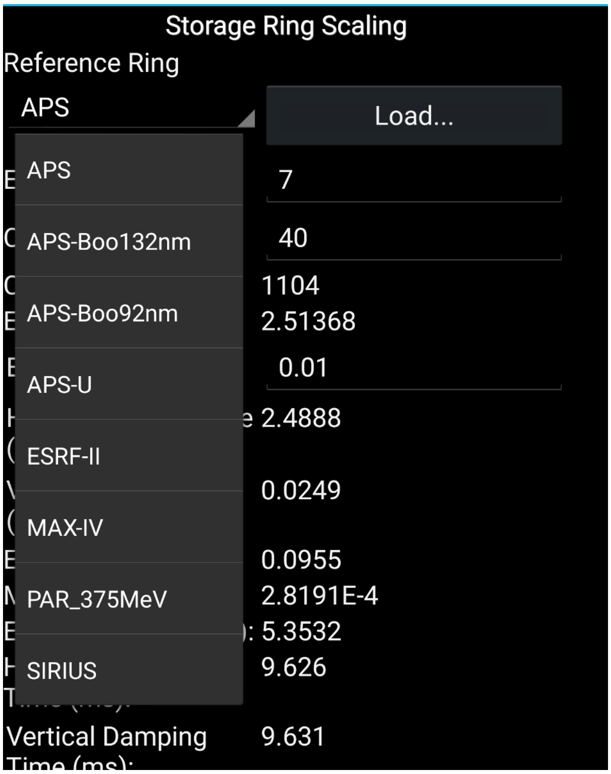

Figure 2: Example of Storage Ring Scaling activity with lattice chooser.

Several improvements have been made to activities related to longitudinal dynamics in rings. Two new activities calculate various aspects of beam loading, namely, for main rf cavities and parasitic cavity modes. Calculations for a higher harmonic cavity for bunch lengthening or shortening were also added. An example for the APS upgrade 67-pm lattice [7] is shown in Fig. 3. In addition to optimizing the harmonic cavity voltage for optimum lengthening, one can simultaneously optimize the main cavity to maintain a specified bucket height.

Two other new activities are: calculation of the CSR instability threshold based on [8]; and computation of matched booster circumference for off-momentum operation (to reduce the extracted emittance) assuming a common rf system for the ring and booster.

Several interesting improvements were made to other activities: top-up and swap-out calculations now include estimates of the power load due to lost and dumped beam; storage ring scaling now computes the coupled emittances including the effect of having $J_x \neq 1$.

Undulators

TAPAs has several models for computing properties for planar hybrid permanent magnet and superconducting undulators (SCUs). Added to this is estimation of properties for helical SCUs, based on work of S. Kim [9]. An example of using this for the planned HSCU for APS is shown in Fig. 4. Additionally, an activity was added to help in translating aperture limits between straight sections with differing apertures and beta functions.

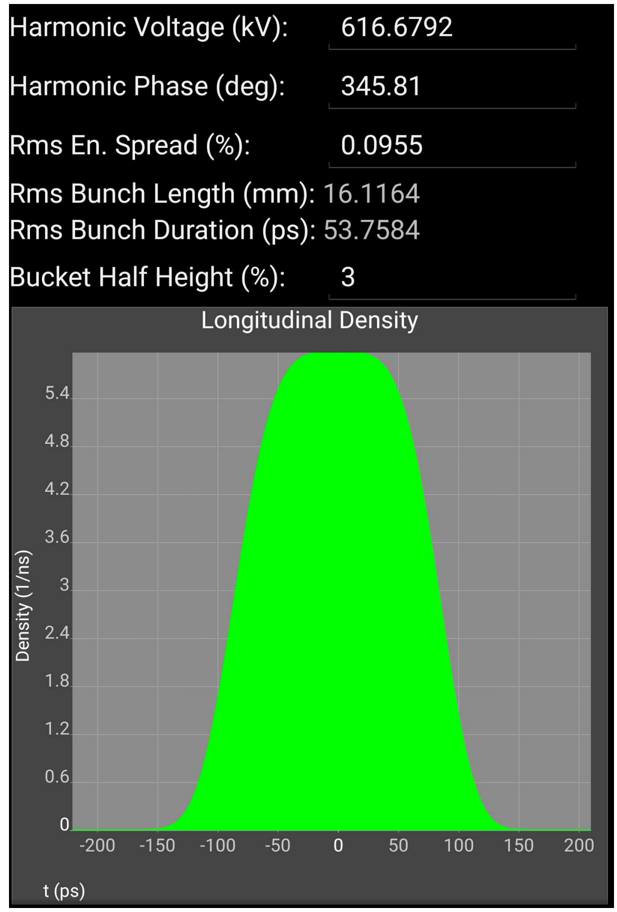

Figure 3: Example of optimization of a 4th-harmonic bunch lengthening cavity for the APS upgrade.

Synchrotron Radiation

Calculation of undulator brightness was added based on [10], with the effect of electron beam energy spread on the bandwidth also included [11]. In particular, the equation is

$$B \approx \frac{F_{\mathrm{CC}}}{(2\pi)^2 \Sigma_x \Sigma_{x'} \Sigma_y \Sigma_{y'}} \frac{1}{\sqrt{1+(5\sigma_\delta h N)^2}}, \quad (1)$$

where F_{CC} is the central cone spectral flux, σ_δ is the rms fractional energy spread, h is the harmonic number, and N is the number of undulator periods. Σ_x, $\Sigma_{x'}$, etc. are the total rms photon beam sizes and divergences, obtained by quadrature addition of the electron beam dimensions and intrinsic photon beam dimensions, given by $\sigma_r = \sqrt{\lambda/N}$ and $\sigma_{r'} = \sqrt{\lambda N}/(4\pi)$.

This equation was found to give reasonable agreement with more sophisticated methods, e.g., the program `sddsbrightness` [12]. Figure 5 shows an example for the APS upgrade lattice, where the properties of the SCU source were computed using the planar SCU activity and transferred automatically.

Also new in TAPAs is calculation of x-ray properties for Compton backscattering.

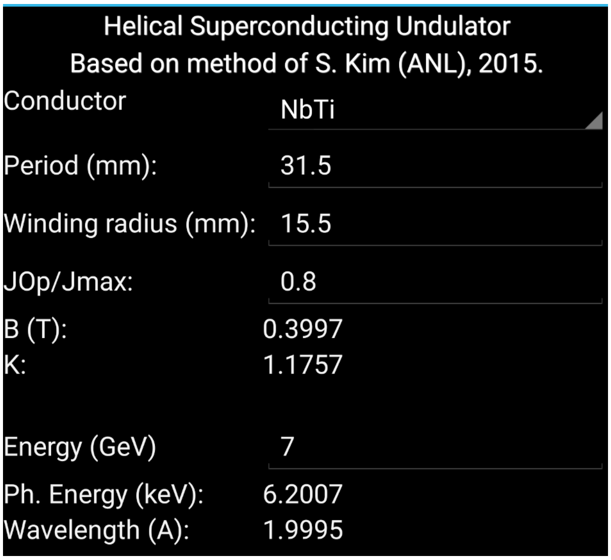

Figure 4: Example of helical SCU calculation for APS prototype device.

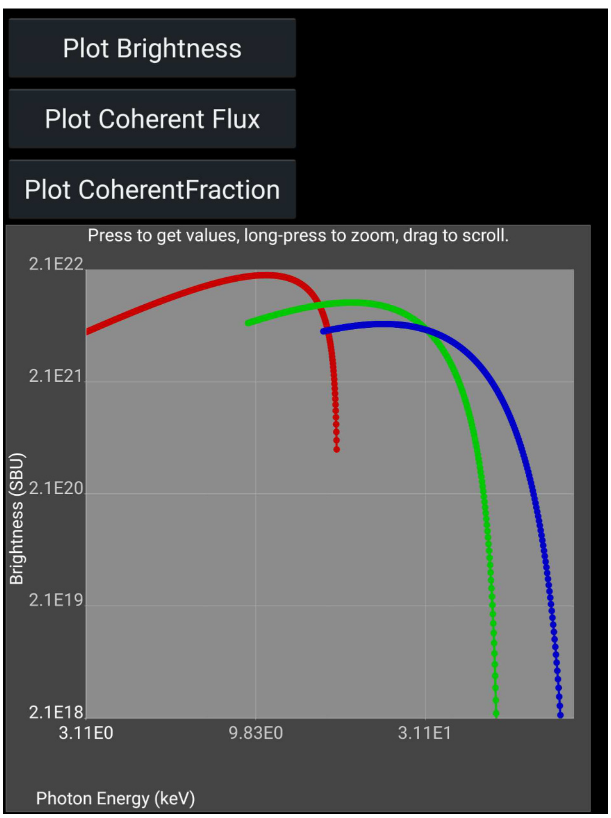

Figure 5: Example of undulator brightness curves for the 67-pm APS upgrade lattice with a 20-mm-period SCU.

Electromagnetism

This submenu has a number of additions: calculation of magnetic fields from straight wires, wire loops, and solenoids; calculation of Kilpatrick's criterion for the voltage limit on conductors [13]; temperature rise from pulsed rf heating [14]; calculation of rf cavity properties, such as voltage, power, and bandwidth; and calculation of bunch form factors for various bunch shapes.

Miscellaneous

Two other new activities are worth mentioning briefly. In the engineering list, calculation of mixing water temperature was added; it can be used, for example, to determine how much cold water to mix with boiling water to 90C water for green tea. In the particle passage through matter list, computation of electromagnetic shower attenuation was added [15].

CONCLUSIONS

The cost- and ad-free TAPAs application for Android devices provides an increasing number of quick, convenient, and sophisticated methods for use in accelerator-related physics and engineering calculations. As the calculations performed by TAPAs become more sophisticated, the need arises for saving and loading settings, exporting data, performing parameter scans, and performing optimizations of output quantities (i.e., seeking a certain value). Features of this nature are envisioned for a future version. The author hopes that it will prove useful and encourages users to send comments, suggestions, and bug reports to michael.d.borland@gmail.com.

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