Electron Weibel instabiliy: movies legend

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Problem setup

Initial electron distribution:

$$f_0(\vec{v}) = \frac{n_0 \exp\left(-\frac{v_x^2}{u_x^2} - \frac{v_y^2}{u_y^2} - \frac{v_z^2}{u_z^2}\right)}{\pi^{3/2} u_x u_y u_z}$$

where n_0 is the density of electrons, u_x, u_y, u_z are the thermal velocities of the electrons along the corresponding axes.

Initial thermal velocity u_x:	0.0447 $[c]$.
Initial thermal velocity u_y:	0.0447 $[c]$.
Initial thermal velocity u_z:	0.1414 $[c]$.
Initial anisotropy parameter A:	9.
Calculation plane:	x-y
Domain size:	25×25 $[c/\omega_{\text{pe}}]$
Mesh grid size:	256×256
Particles per cell:	2000 electrons, 2000 ions (immobile).
Total number of particles:	$1.3 \cdot 10^8$ electrons, $1.3 \cdot 10^8$ ions (immobile).
Simulation time:	1000 $[1/\omega_{\text{pe}}]$.
Time step:	0.25 $[1/\omega_{\text{pe}}]$
Number of time steps:	4000.
Boundary conditions:	bi-pereodic.
Particle scheme:	2-nd order on time and space, implicit.
Field equation:	Darwin fields in elliptic formulation.
Computational time:	20 hours.
Computational power:	128 cores of Xeon E5472 (16 servers $\times$ 2 CPU $\times$ 4 cores).

Important note:

Above stated setup is slightly different comparing to the one considered in the paper "Single-Species Weibel Instability of Radiationless Plasma" (http://arxiv.org/abs/0910.0361). *In the current setup $A = 9$ as it is in the paper, but temperatures along each axis are 2 times higher than in that case, number of particles per cell is also 2 times higher.*

File: EWI09.wk.wB.A.Jz+B.(sm).avi

Description:	Animation shows evolution of J_z together with magnetic field and various components of system's energy.
File URL:	http://darwincode.org/movies/EWI09.wk.wB.A.Jz+B.(sm).avi
File size:	24.7 Mb
Resolution:	1280×1024 @ 20 FPS
Postprocessing:	Medium temporal smoothing to reduce PIC noise.
Codec:	MPEG-4 Advanced Simple Profile (ASP). http://xvid.org

Upper left plate

Vertical axis	Energy density in units of $[n_0 m_e c^2]$.

Horizontal axis		Time in units of $[1/\omega_{\rm pe}]$.
w_{kx}	(dashed red)	x-component of average kinetic energy density of electrons.
w_{ky}	(solid green)	y-component of average kinetic energy density of electrons.
w_{kz}	(solid blue)	z-component of average kinetic energy density of electrons.
w_k	(solid black)	Average kinetic energy density of electrons ($w_k = w_{kx} + w_{ky} + w_{kz}$).
$w_{\rm total}$	(solid gray)	Total average energy density of the system (ion's energy is not accounted).
w_B	(dashed black)	Average magnetic field energy density.

Upper right plate

Vertical axis		Energy density in units of $[n_0 m_e c^2]$.
Horizontal axis		Time in units of $[1/\omega_{\rm pe}]$.
w_{Bx}	(dashed red)	x-component of average magnetic field energy density.
w_{By}	(solid green)	y-component of average magnetic field energy density.
w_{Bz}	(solid blue)	z-component of average magnetic field energy density.
w_B	(solid black)	Average magnetic field energy density ($w_B = w_{Bx} + w_{By} + w_{Bz}$).

Lower right plate

Vertical axis		Average anisotropy calculated as $A = 2u_z^2/(u_x^2 + u_y^2) - 1$.
Horizontal axis		Time in units of $[1/\omega_{\rm pe}]$.

Lower left plate

$J_z(x, y)$	(color map)	Current density in units of $[n_0 q_e c]$.
$B_{xy}(x, y)$	(vectors)	Magnetic field.

Note: two horizontal marks on the color bar indicate current minimum and maximum values of J_z calculated on smoothed J_z.

File: EWI09.n.wB.wk+B.Jz+B.(sh).avi

Description:	Animation shows evolution of J_z together with magnetic field, density of electrons, kinetic energy density and average density of magnetic field energy.
File URL:	http://darwincode.org/movies/EWI09.n.wB.wk+B.Jz+B.(sh).avi
File size:	82.6 Mb
Resolution:	1280 × 1024 @ 20 FPS
Postprocessing:	High temporal smoothing to reduce PIC noise.
Codec:	MPEG-4 Advanced Simple Profile (ASP). http://xvid.org

Upper left plate

$n_e(x, y)$	(color map)	Density of electrons in units of $[n_0]$ (normalized to be 1.0 in average).

Upper right plate

Vertical axis		Energy density in units of $[n_0 m_e c^2]$.
Horizontal axis		Time in units of $[1/\omega_{\rm pe}]$.
w_B	(solid black)	Average magnetic field energy density.

Lower right plate

$w_k(x, y)$	(color map)	Kinetic energy density of electrons in units of $[n_0 m_e c^2]$.
$B_{xy}(x, y)$	(vectors)	Magnetic field.

Lower left plate

$J_z(x, y)$	(color map)	Current density in units of $[n_0 q_e c]$.
$B_{xy}(x, y)$	(vectors)	Magnetic field.

File: EWI09.wkx+B.wky+B.wkz+B.Jz+B.(sh).avi

Description:	Animation shows evolution of J_z together with magnetic field and three components of kinetic energy density.
File URL:	http://darwincode.org/movies/EWI09.wkx+B.wky+B.wkz+B.Jz+B.(sh).avi
File size:	50.7 Mb
Resolution:	1280×1024 @ 20 FPS
Postprocessing:	High temporal smoothing to reduce PIC noise.
Codec:	MPEG-4 Advanced Simple Profile (ASP). http://xvid.org

Upper left plate

$w_{kx}(x,y)$	(color map)	x-component of kinetic energy density of electrons in units of $[n_0 m_e c^2]$.
$B_{xy}(x,y)$	(vectors)	Magnetic field.

Upper right plate

$w_{ky}(x,y)$	(color map)	y-component of kinetic energy density of electrons in units of $[n_0 m_e c^2]$.
$B_{xy}(x,y)$	(vectors)	Magnetic field.

Lower right plate

$w_{kz}(x,y)$	(color map)	z-component of kinetic energy density of electrons in units of $[n_0 m_e c^2]$.
$B_{xy}(x,y)$	(vectors)	Magnetic field.

Lower left plate

$J_z(x,y)$	(color map)	Current density in units of $[n_0 q_e c]$.
$B_{xy}(x,y)$	(vectors)	Magnetic field.

File: EWI09.Jz+B+Particles.(sh).avi

Description:	Animation shows motion of selected electrons together with the evolution of J_z.
File URL:	http://darwincode.org/movies/EWI09.Jz+B+Particles.(sh).avi
File size:	188 Mb
Resolution:	1280×1024 @ 15 FPS
Postprocessing:	High temporal smoothing to reduce PIC noise.
Codec:	MPEG-4 Advanced Simple Profile (ASP). http://xvid.org

Main plate

$J_z(x,y)$	(color map)	Current density in units of $[n_0 q_e c]$.
$B_{xy}(x,y)$	(vectors)	Magnetic field.
e_{+v_z}	(blue points)	Electrons who's initial velocity $v_{z0} \gg 0$. In the experiment 25% of electrons with highest initial velocities along *positive* direction of z-axis are marked to be a "blue group". Only 750 electrons of the total "blue" group are shown in the animation.
e_{-v_z}	(red points)	Electrons who's initial velocity $v_{z0} \ll 0$. In the experiment 25% of electrons with highest initial velocities along *negative* direction of z-axis are marked to be a "red group". Only 750 electrons of the total "red" group are shown in the animation.

File: EWI09.xVx.wB.yVy.Jz+B.avi

Description:	Animation shows the evolution of J_z together with phase space evolution.
File URL:	http://darwincode.org/movies/EWI09.xVx.wB.yVy.Jz+B.avi
File size:	32.4 Mb
Resolution:	1280×1024 @ 20 FPS
Postprocessing:	none.
Codec:	MPEG-4 Advanced Simple Profile (ASP). http://xvid.org

Note:

Total population of the particles was grouped into 3 sets as follows,
set A: 25% of the total particles with the highest v_z along z (the same as "blue" group above).

set B: 50% of the total particles with the v_z around zero.
set C: 25% of the total particles with the highest v_z opposite to z (the same as "red" group above).

Upper left plate

Phase plots of the sets A, B, C. From top to bottom:

A: x, vx	(color map)	Phase space density of electrons of the set A.
B: x, vx	(color map)	Phase space density of electrons of the set B.
C: x, vx	(color map)	Phase space density of electrons of the set C.

Upper right plate

Vertical axis		Energy density in units of $[n_0 m_e c^2]$.
Horizontal axis		Time in units of $[1/\omega_{\mathrm{pe}}]$.
w_B	(solid black)	Average magnetic field energy density.

Lower right plate

Phase plots of the sets A, B, C. From left to right:

A: y, vy	(color map)	Phase space density of electrons of the set A.
B: y, vy	(color map)	Phase space density of electrons of the set B.
C: y, vy	(color map)	Phase space density of electrons of the set C.

Lower left plate

$J_z(x, y)$	(color map)	Current density in units of $[n_0 q_e c]$.
$B_{xy}(x, y)$	(vectors)	Magnetic field.