"Review of The Grishuk and Sachin GW Generator Via Tokamak Physics"

Andrew Beckwith*

1. Chongqing University Department of Physics — Chongqing, P.R.C.
   400014 (Postal Code)

abeckwith@uh.edu

* Co-authors will be selected from people in Chongqing University Physics Department in the document submitted for peer review.

A beckwith@uh.edu

1) Email for correspondence as to future physics article:
Review of the Grischuk and Sachin GW Generator Via Tokamak Physics

Abstract

Using the Grischuk and Sachin amplitude for GW generation due to plasma in a toroid we generalize this result for tokamak physics. We obtain evidence for strain values up to $h \sim 10^{-24}$ in the center of a tokamak which may be detectable in the near future. Details as to $M_{\text{ions}} \gamma c > 1.5 \times 10^{20} \text{ m}^3 \text{ s}^{-1}$ may allow for a confinement time $T_E$ sufficiently long as to permit falsifiable measurement of GW in the coming near future.

1. Introduction:

In 1975 in [1], Russian physicists
Grishchuk and Sachin obtained the following amplitude for GW generated by plasma in a toroid:

\[ A \propto G \cdot E^2 \cdot \lambda_{\text{GW}} \]  

Here, \( E \) is the E field in the plasma and \( \lambda_{\text{GW}} \) is the GW wavelength.

Note: if \( \lambda_{\text{GW}} \sim 10^6 \text{Hz} \), then \( \lambda_{\text{GW}} \sim 360 \text{ meters} \).

In order to fit the \( \lambda_{\text{GW}} \) within 3DSR technology \([2]\), we use \( \lambda_{\text{GW}} \sim 10^9 \text{Hz} \) for \( \lambda_{\text{GW}} \sim 0.3 \) meters, which puts a premium on E (electric field) construction.

The 1st attempt to obtain E results was initiated using a simplified Ohms Law, via

\[ J = \sigma \cdot E \quad (2) \]

This lead to unsuitably small A (GW) results, which mean
we have looked at a generalization of Ohms law, of the form

\[ E = \sigma \left( J - \nabla \times B \right) \]  

i.e., both \( E \) and \( B \) fields,

as well as we will explain an expression for radial \( E \) fields

\[ \eta_i \cdot e_i \cdot (E_r + \nabla \cdot B) = -\frac{dP_j}{dt} \]

where \( \eta_i \) = ion density, \( i \) species

\( e_i \) = ion charge, \( i \) species

\( E_r \) = radial \( E \) field

\( \nabla \cdot B \) = perpendicular velocity (of ions), \( i \) species

\( B \) = magnetic field

\( P_j \) = pressure, \( j \) species

The results of using (3) and (4) are that will obtain

\[ A_0 E \approx \frac{\lambda_0}{\varepsilon_0} \approx \frac{\lambda_0}{\varepsilon_0} \left( \frac{c}{n_e} \right)^2 \approx \frac{\lambda_0}{\varepsilon_0} \left( \frac{c}{n_e} \right)^2 \]
\[ A \approx (1) + (2) \]

\[ A \uparrow \text{term due to} \uparrow \text{term due to} \]

\[ \Phi = E = 0 \quad \quad \text{En} = \oint - (\mathbf{v} \times \mathbf{B}) \cdot \hat{n} \frac{dS}{\partial n} \]

\[ E = \text{[const]} \quad \frac{\Phi}{R} \]

**1st term will yield:**

\[ h \approx 10^{-38} \text{ to } 10^{-30} \text{ for} \]

3 DSRS 5 meters above

Tokamak Ring

**2nd term will yield:**

\[ h \approx 10^{-28} \text{ for } 100 \text{ keV (or higher)} \text{ temp} \]

for 3 DSRS 5 meters above

Tokamak Ring

(see page 12 for)

**2i.** Acw derived using simplified ohms law \( i = 0 \text{ m}\)

Start 1st with (Table 1)

Current for different Tokamaks:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Site</th>
<th>Plasma Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>JET</td>
<td>Culham (UK)</td>
<td>5-7 MA</td>
</tr>
<tr>
<td>ASDEX</td>
<td>Garching (Ger)</td>
<td></td>
</tr>
<tr>
<td>DII-D</td>
<td>San Diego (USA)</td>
<td></td>
</tr>
<tr>
<td>HL-2A</td>
<td>Chengdu (PRC)</td>
<td>0.45 MA</td>
</tr>
<tr>
<td>HT-7U</td>
<td>Heifei (PRC)</td>
<td>0.25 MA</td>
</tr>
<tr>
<td>J-TER</td>
<td>Saint Paul (France)</td>
<td>15 MA</td>
</tr>
</tbody>
</table>
1. \( A (Gw) \) center of ring \( \sim 10^{-36} \)

2. \( A (Gw) \) center of ring \( \sim 10^{-38} \)

3. \( A (Gw) \) center of ring \( \sim 10^{-32} \)

4. \( A (Gw) \) center of ring \( \sim 10^{-34} \)

5. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

6. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

7. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

8. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

9. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

10. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

11. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

12. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

13. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

14. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

15. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

16. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

17. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

18. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

19. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

20. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

21. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

22. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

23. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

24. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

25. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

26. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

27. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

28. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

29. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

30. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

31. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

32. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

33. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

34. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

35. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

36. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

37. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

38. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

39. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

40. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

41. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

42. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

43. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

44. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

45. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

46. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

47. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

48. \( A (Gw) \) center of ring \( \sim 10^{-29} \)

49. \( A (Gw) \) center of ring \( \sim 10^{-31} \)

50. \( A (Gw) \) center of ring \( \sim 10^{-29} \)
3. Enhancing
Amplitude: Revisit
Ohm’s Law

Look at surface
E field with [E]

Note:

\( V_R \)

is usually
small,
can usually be neglected:

\[ E = \left[ \frac{\partial \mathbf{J}}{\partial t} \right]_{\text{net}} = \left( V \times \mathbf{B} \right)_m \sim V_R \mathbf{B} \mathbf{\theta} \]  
(7)

THEN

\[ E = -\mathbf{B} \mathbf{\theta} \cdot \left( \frac{\partial \mathbf{J}}{\partial t} + V_R \mathbf{B} \mathbf{\theta} \right) \]  
(8)

where we used [E]

\[ \mathbf{d} \mathbf{p}_j = -\mathbf{B} \mathbf{\theta} \cdot \mathbf{J} \]  
(9)

\[ \mathbf{E} = \frac{\mathbf{2}}{\mathbf{R}} \]  
whose
\( \mathbf{2} = \mathbf{R} \)
inner
Tokamak
ring,
R.o.
Radial
direction

If
\[ \mathbf{J}_B \sim -\frac{\mathbf{\theta}}{\mathbf{R}} \cdot \mathbf{T}, \quad \mathbf{d} \mathbf{J}_B + \mathbf{R}_M \]  
(10)

Then

\[ B \mathbf{\theta} \cdot \left( \frac{\mathbf{J}_B}{\text{net}} \right) \sim \frac{B^2}{\mathbf{e}_t^2} \cdot \frac{\mathbf{3}}{\mathbf{4}} \left[ \frac{1}{\mathbf{e}_t^2} \cdot \left( \mathbf{d} \mathbf{J}_B + \mathbf{R}_M \right) \right]^{-2} \]  
(11)
\[ \frac{1}{\bar{v_0}} \frac{d\bar{v_0}}{dr} = \frac{d}{dr} \ln(\bar{v_0}) \]

Then

\[ \bar{v_0} \]

Then the second term from \textit{Tokamak} generated \( G \omega \) amplitude, namely from Eq. (5), has

\[ G \frac{B_0^2 \mu_0^2}{c^4} \frac{\lambda^2}{\bar{v}_0} \sim \frac{c^4}{\bar{v}_0^2 \rho_{\text{ion}}} \left[ \frac{2 \pi \hbar e T_{\text{Temp}}}{m_e} \right]^2 \lambda^2 \]

This assumes using \( T_{\text{Temp}} \) from ignition of \textit{Tokamak} for \( T_{\text{Temp}} \sim 10^2 \) (fusion) plasma with strain

\[ \sim 10^{-25} \text{ for } T_{\text{Temp}} > 10 \text{keV} \]

\[ G \frac{B_0^2 \mu_0^2}{c^4} \frac{\lambda^2}{\bar{v}_0} \sim \frac{c^4}{\bar{v}_0^2 \rho_{\text{ion}}} \left[ \frac{2 \pi \hbar e T_{\text{Temp}}}{m_e} \right]^2 \lambda^2 \]

Preliminary calculations

From Wesson [D-T plasma] [2]

have a criteria for ignition

\[ m_i \cdot T_{\text{Temp}} \cdot \tau_e > [3 \times 10^{21} \text{ m}^{-3} \text{ keV}] \cdot 8 \]

where \( \tau_e = \text{seconds} \), \( m_i = \text{meters} \)

\[ T_{\text{Temp}} \sim 10^2 \text{ keV} \]

\[ \rho_{\text{ion}} \sim 10^{24} \text{ m}^{-3} \]
\[ T_e \approx 3 \text{ seconds} \quad (16) \]

This for confinement of plasma.

Using Temp \( \approx 10 \text{ keV} \)

Using \( \Delta x \approx 0.3 \text{ meters} \)

Using \( \omega \approx 10^9 \text{ Hz} \)

Then Eq. (14) is approximately \( 10^{-26} \).

Looking at Figure 1-5.1 of Wessom [3], (Page 11)

if one increases Temp up to

Temp \( \approx 100 \text{ keV} \)

Then Eq. (14) is approximately \( 10^{-24} \).

Positioning 3DSR detection device \( \approx 5 \) meters above Tokamak:

\[
\frac{G}{C_4} = \frac{B_0^2 \Delta \nu \lambda_e}{2} \quad (17)
\]

\[
\frac{n_{\text{drift}} e_0}{C_4} \approx \frac{10}{26} \quad (17)
\]

\[ \text{5 meters above Tokamak} \]
4. Can impurities in plasma lengthen $T_E$?

Textor Tokamak

Lengthen $T_E$ via seeding plasma with impurities ~ say argon, or neon.[13]

Then

Let $T_E = \frac{\eta_{\text{seed}}}{\eta_{\text{seed}}}$

where $\eta_{\text{seed}}$ is numerical density of argon/ neon in plasma

See Figure 1.5.1 of Wesson

Page 11
5. conclusion

Limited Ohms law, with
\[ J = \sigma E \]
leads to
GW strain amplitude values
from \(10^{-38}\) to \(10^{-30}\) for
a GW (3DSR) 5 centimeters above a Tokamak ring.

We add a heat current
\(\Phi\) to physics dynamics
to GW
\[ A_{gw} \sim E \cdot E^2 \cdot \lambda_{gw} \]
with \(E\) amplified via
an extension of Ohms law,
\[ \text{Law}. \]

Then
\[ A_{gw} \sim 10^{-24} \]
for
\[ T > 10 \text{ keV}, \]
and
\[ A_{gw} \sim 10^{-24} \]
in center
of Tokamak ring. Then
\[ A_{gw} \sim 10^{-26} \]
for 3DSR GW detector 5 meters above
tokamak ring. Note, we used
temperature dependence from ion trapping in reaction [3], page 162
for Tokamak for our temperature scaling.
Bibliography:


& R.C. Woods et al., Journal of Modern Physics 2, NO 6, starting at page 498 (2 011)

Each 'Face' of the toroid

The coordinate system used leads to the following magnetic flux \( \text{through surfaces} \) [2]

From [2]: magnetic flux surfaces forming a nested set of 'Toroids'