Ideas for creative experiments and applications

"Everyone knew it was impossible to do, one day an ignorant arrived and... did it!"

Marcel Pagnol

The electromagnetic Non-Radiative Near-Field domains are wonderful playing grounds for modern experimenters. Don't be afraid by the barbarous terms: "Non-Radiative" and "Near-field", these domains, two in fact, concern simply electric and magnetic distant forces and are nothing more than playing with magnets and distant electric charges using modern means. Aside well known mechanical applications of such forces, for instance dust removers or electrostatic painting for the electric side and the huge family of magneto-electric generators that empower our modern world in the magnetic side, some other solid-state applications are rediscovered nowadays. Who knows how many are waiting a future innovator!

In these modern applications nothing is apparently moving, the forces apply between invisible charges free to move inside conducting materials. As a large amount of inertia forces is removed (electrons are very lightweight particles), electric and magnetic forces can be used at much higher rates than in case of moving bodies applications. This enables for the electric force much larger power transfer possibilities than what was possible in previous centuries for electrostatic machines. Said otherwise, in the modern electronic circuits' frame both technologies, that we call Influence and Induction, play on equal footing. Surprisingly, the modern Influence technology has a decisive advantage over its old competitor Induction as it leads to lower currents and then lower dissipation inside conductors.

Many readers should be puzzled by so many nebulous terms such as: "distant forces", "solid state applications", "higher rates", "Influence", "Induction" and "dissipation". Just be patient, Kantanlabs provides many tools to realize enlightening experiments and all the necessary knowledge you need to understand how such technologies work.
In this document we propose a progressive series of exciting experiments, easy to make and to explain. These experiments are appropriate for a large audience, even those among you having, according to modern teaching standards, a very poor level in mathematics and physics[1]. The main prerequisite is to be motivated to discover, in your own personal way if you wish, the fundamental rules the universe is following. All the great discoveries were and will be made by people not tighten to follow the main stream path.
In the following we suggest experiments ordered by increasing practical and conceptual difficulties but fill free to pick your choice.

[1] Faraday as well as Tesla had very poor knowledge and understanding of existing mathematical formulations available in their respective times.

I -<u>Expected prerequisites</u>

KanTanLabs provides tools and kits that can be easily assembled. Demonstrations could be made for any curious audience provides the vocabulary and the conceptual level is adapted to the audience. However the experimenter is expected to have at least a general knowledge in sciences and some elementary laboratory type skills.

The expected general scientific knowledge is:

- Electricity basic rules (the current, voltage concepts and general circuit's rules).
- Some elementary mechanical notions such as oscillations and forces.
- The classical notion of fields (seen as related to some action at a distance).

To go farther the experimenter should also be able to make some elementary measurements, using for instance a digital multimeter or a scope.

Basic explanations involving no math are provided in the Basic stuff section.

<u>Remarks for students and teachers</u>

Our past experience has shown that people with only a basic scientific knowledge are often much more receptive to near-field specificities than many specialists that are falsely convinced they understand the whole EM domain.
The main reason for this surprising situation is that conventional physics books lack a clear introduction to such phenomena that lie close to the static domains but also involve some dynamic aspects such as the possibility for wireless power transfer.
A good example is to consider the charge and discharge of a capacitor: this process is in no way static, as it involves some exponential variations with time of voltage and current, but produces at low frequency only a negligible amount of radiated energy at some distance.
The existence of these two dynamic but non-radiating domains (one to describe the charge/discharge of a capacitor and another one to describe the charge/discharge of a coil) is, according to us, not described in a satisfying manner in most academic courses. For instance wave propagation is given a so large importance that many students falsely assume that all EM phenomena arising in the vacuum at some distance from sources can only be explained by travelling waves. Just try to wonder how capacitors or coils could be surrounded with energy due to waves and you will soon understand how such a frame is inappropriate to describe near-field situations and how they enable wireless power transfer.

Said otherwise, the limits between these two dynamic but non radiating domains, namely Influence and Induction, and the wavelike paradigm are nebulous for most students and even many teachers. To bridge this knowledge gap KantanLabs also provides more elaborate content that you will find under the Mind boggling stuff section.

II - Summary of basic concepts

Let’s no introduce the very basic concepts that enable a clear understanding of non-radiative near-field devices.

1 - First of all and as surprising as it may seem for many modern physicists, the main idea is: **no propagating waves allowed! Even evanescent ones!** Everything can be very well described and understood through equations and concepts already existing well before Maxwell work and EM-waves discovery.

2 - Surprisingly, even for electrical dipoles, energy is mainly stored externally in a totally reversible manner over distances that practically extend to several times the dipole length.

3 - Resonance and attached Q-factor are technologic ways to reduce losses inside the dipoles for the same external field level but in no way alters the external field and the coupling between two distant dipoles.

4 - The energy transfer between two distant dipoles can easily be understood through the idea of distant instantaneous force as for two interacting magnets or two interacting electrostatic charges. This concept also explains why coupling is larger for dipoles aligned along the same axis whereas in the propagation frame the radiated flux is zero in the longitudinal direction.

5 - The transition between this near-field mechanical behavior and far-field wavelike behavior is still a conceptual open issue for modern physics.

Readers interested to excavate some more the conceptual incompatibilities between the near-field concepts and the far field ones are encouraged to read: Some more explanations about basic concepts.pdf in the **basic stuff** section.

III - Suggested fun experiments

Some examples are briefly described below; we will add more content in our YouTube channel soon, stay tuned.

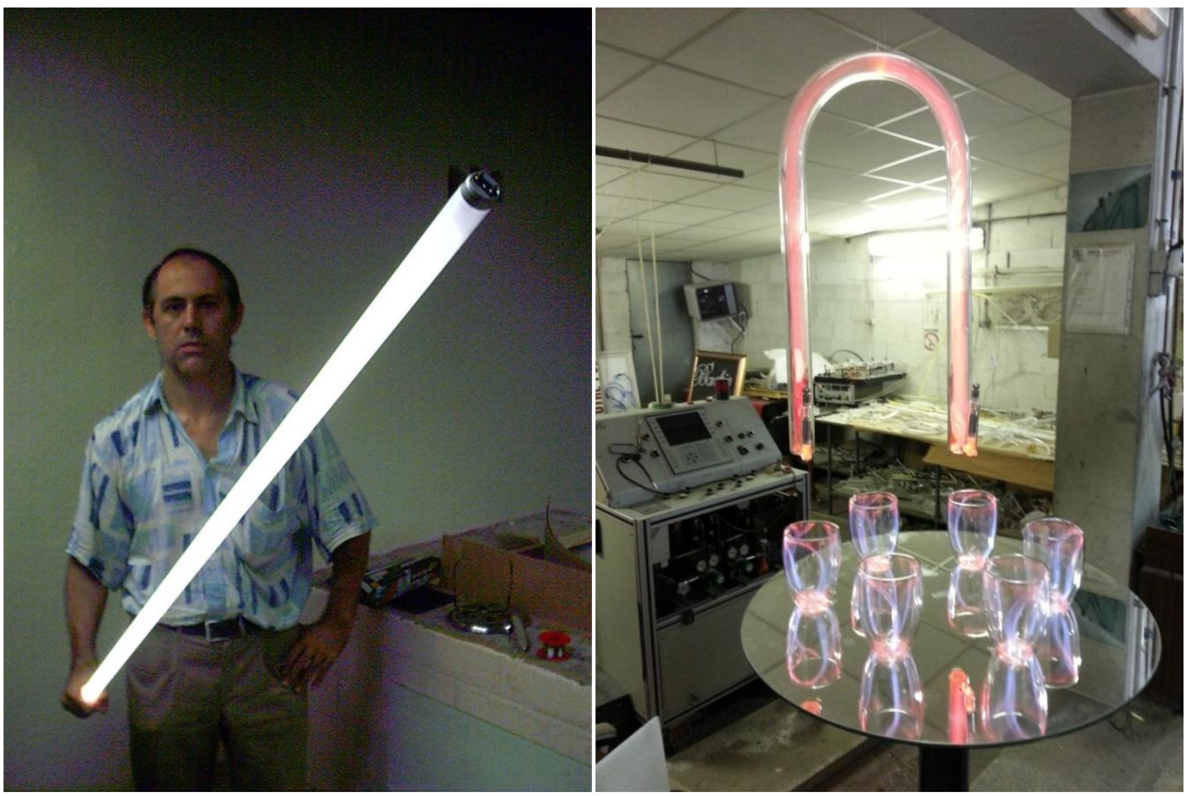
1 - Lighting neon tube at a distance (Jedi light-saber & Neon art)

With high electric fields it is possible to light a new or used fluorescent tube[2].

With a signal generator working as a power source a nice glow can be obtained in dark conditions (with a standard signal generator the maximum power available is only 250mW in a 50Ω resistive load). However working at low power input and low stored energy allows totally safe and fun investigations.

Using larger input power will allow much brighter results with however an increasing risk of slight skin burning if a proper insulation is not provided.

The maximum range depends more on electrode size than in power levels, with large electrode it can easily reach several meters.



A large electrode provides a larger range and volume

[2] Even if the tube is too old to be normally lighten (for instance if it's only flashes or partially lightens or presents large dark regions on the sides), it might be lighten again provides it is not broken (the low pressure gas should remain inside).

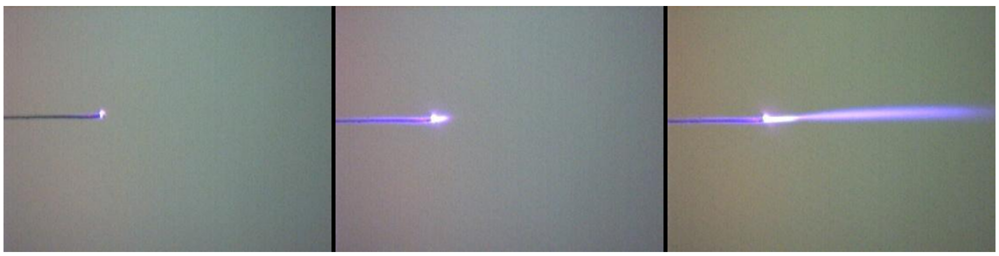
Our generators are also used to light at some distance neon art type objects:

Wireless neon art © Fathlight 2014

For more on wireless neon art you may contact Mr Abiola from Fahtlight.

2 - <u>Producing AC corona glows</u>

For voltages in the kV range or above, one may observe ionization around sharp edges. With our product it will be easy to visualize and study the stability of such a corona discharge and the transition toward a full thermal breakdown[3]. When no current limitation is provided or when capacitors with high energy storage are involved, the thermal runaway is usually destructive. With KantanLabs products, experimenting with such breakdown conditions is easy and safe[4].



Normal glow **Limit of stability** **Streamer regime**

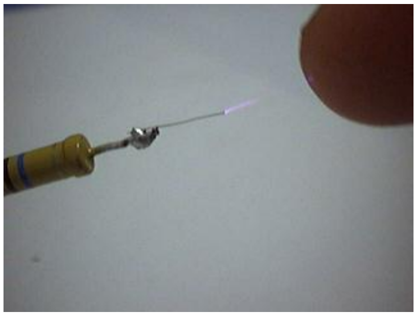
Our products will allow you to produce high-voltages at relatively high frequencies. We may provide high quality resonant circuits for frequencies ranging from a few tens of kilohertz up to several megahertz. However, above 1Mhz the voltage threshold to light a corona or even a neon tube increases as the ions and electrons have less time to be accelerate in order to produce the avalanching ionization process involved in a glow discharge.

The main advantages of AC current glows is that you do not need an electrode in front of the tip to catch drifting charges in order to close the current loop. In AC glow the charges neutralize naturally at a short distance from the tip and the circuit is closed by a virtual current loop (see the basic stuff section for more explanations).

[3] When a hot channel is formed, the channel resistance drops according to temperature rise and currents circulate in an exponential process

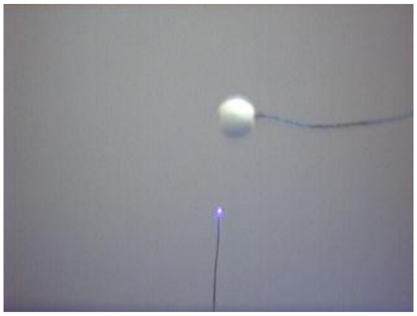
[4] If no flammable materials are involved in the experimenting area.

With AC coronas there is are no electrostatic charge that may lead to troubles. It result that the space in front of the tip is totally accessible for investigations.



Because of charge recombination the experimenter's finger feel no discomfort

A continuous current corona induces some electric wind because ions of the same polarity than the high-voltage conductor are repelled and drag neutral particles through collisions along their trajectories. An AC current corona produces the same effect although in a reduced manner depending of frequency. This can be easily shown using a small strip of paper or a very light ball made of polystyrene for instance.



A light weight ball to show the electric wind presence

More information on electric wind and related applications is provided: here.

3 - Making your own HVgenerator for other electrostatic experiments

With KanTanlabs tools and parts, the skilled amateur will easily build a High-Voltage DC power supply in order to realize many electrostatic experiments in totally safe conditions. He will rapidly forget the common and quite dangerous solution that consists in using a High-voltage transformer found in old CRT monitor or TV-set. As our coils and transformers work at much higher frequencies, the necessary DC filtering capacitance is much smaller so that strong electric shocks will be totally avoided even in case of a direct contact with the high-voltage output.

With such versatile generators the skilled amateur, as well as the expert, will be able to make a wide range of mobile or immobile near-field experiments.

Classical investigations with mobile parts are for instance:

- Basic mechanical attraction/repulsion experiments with electrically charged bodies
- Motors (such as an electrostatic pinwheel or more sophisticated devices)
- Generators (to produce even higher voltages using a carrying belt for instance)

Solid state devices may concern:

- Electric wind (the ions produced by a corona glow are used to transfer energy to the surrounding fluid in order to blow a candle for instance).
- Lifter (the same effect is used to produce a reaction force in order to sustain a light device).
- Ionic speakers (the electric wind is converted into sound waves when an audio modulation is provided).

An operating lifter in flight

More on lifters (for advised readers) is provided: here (see: Basic course & model/The lifters' basic physics).
More information on plasma speakers is provided: here (see: Industrial issues/acoustics).

4 - <u>Making your own ferrous and non ferrous detector (the tresor hunter's experiment)</u>

Because of their very large Q-factors, our resonant magnetic and electric dipoles are very sensitive relative to external conditions. They may be used to study a large number of non-contact sensors.

Magnetically sensitive sensors:

A magnetic dipole will react to the presence of a metallic body in two different ways:

- If the conducting body is made of non-ferrous materials, the frequency will not change but the overvoltage will be reduced because of induced currents in the conductor and their associated losses.

- If the conducting body is made or partly made of ferrous materials the same effect will arise but simultaneously the resonance frequency will also change.

By monitoring the two effects you may not only detect conductors at some distance, but you may also discriminate ferrous and non ferrous ones.

Electrically sensitive sensors:

An electric dipole will react differently:

- Dielectric material will generally alter both the frequency and the Q-factor depending on the loss angle of the dielectric material.

- Conducting materials will alter the behavior differently depending is they are connected to ground or not and according to the shape of the conductive body compared to the shapes of electric field lines[5].

Very little work was done for such capacitive distant wireless sensors. You may for instance think of detector that will be able to discriminate bubbles from other types of inhomogeneities in dielectric substrates. Another possible application for agriculture could be to make a mobile device that will measure through a system of electrodes the water repartition profile in the ground layers and, why not, may even detect the presence of an aquifer if not too deep.

Both types of sensors (magnetic and electric) could be easily combined to make more sophisticated non-contact sensing devices.

[5] For instance a floating conductive sheet that follows equipotential surfaces will have no effect at all but may have a large effect if grounded.

5 - Metals and dielectrics heaters (The wireless hot coffee cup project)

Electric and magnetic dipole can reversely be used to transfer some energy in a dissipative material.

The induction heating process is well known and used. If you have a RF amplify at hand or one of our appropriate generators, our coils are well suited for intermediate power experiments. For instance you may measure the temperature rise obtained in various conducting metals according to metals, distances….

Apart a handful of RF power specialists, the influence heating process in totally ignored: As well as large magnetic fields may lead to strong dissipation in imperfect conductors, strong electric fields may lead to dissipation in imperfect dielectrics[6].

An interesting project would be to maintain indefinitely a cup of coffee at the best temperature. To do so, you have the choice to use an induction coil combined to a metal cup made of a poorly conducting metal or you may innovate by using electric dipoles combined to an appropriate dielectric material. For instance some glass material will fit and will allow making a fully transparent heating cup.

The hot coffee cup project

[6] A dielectric material exhibiting a quite large loss angle

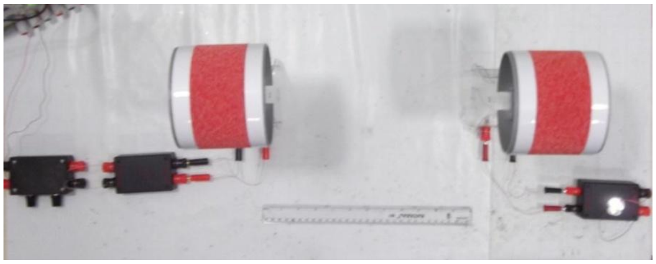
6 - Wireless power experiments

KantanLabs provides parts, tools and kits to demonstrate easily how the two possible wireless non-radiative[7] systems work. These systems use quasi-static electric or magnetic field to carry energy at some distance from the source. More accurately they use an electric or magnetic coupling between two oscillating resonant dipoles of the same kind[8]. As the coupling gets rapidly weak when distance between the dipoles is increased, resonance could be used to recycle the untransferred power in the next alternation leading to much larger efficiencies especially in weak coupling cases. More detailed explanations are given in our food for thought pages.

A scholar type demonstration in the University of Mauritius (UoM)

Inductive wireless power investigations

With a signal generator, two impedance adapters, two resonant magnetic dipoles and a power LED, you will obtain the following result:



A typical inductive wireless power demonstration

The impedance adapters enable to adjust the impedance to fit the generator dipole and the load dipole impedance. In case of induction, the impedance values for the resonant dipoles are smaller than optimum values. Using impedance adapters allows increasing efficiency and range.

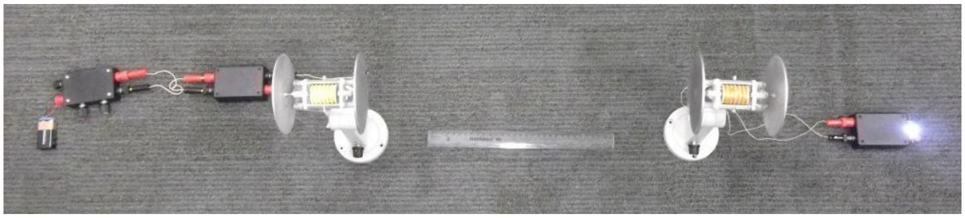
[7] It means that energy is not carried through waves and that a totally negligible amount of power is radiate far away.

[8] It is the solid state counterpart of two oscillating or rotating magnets or two electrostatic pendulums where the mobile elements are only the electrons inside conductors.

If you are not interested in the best performances, you may still obtain demonstrative results for a distance only slightly reduced by connecting directly the two dipoles to a signal generator on one side and a LED on the other side. According to your power source and to tuning conditions, you will be able to transfer up to a few watts over gaps in the decimeter range and a few mW over a distance close to one meter.

Capacitive wireless power experiments

With the same generators, impedance adapters[9] and load; you may obtain similar results for two coupled resonant capacitive dipoles. In the example below the power source is a commercial 9V battery, the power transfer is about 100mW and could be sustained for several hours.



A typical capacitive wireless power demonstration

In both cases many interesting experiments are allowed. Apart the variations according to distances, one may also show the effect of relative angles, of perturbing bodies such as the experimenter hand, of the load resistance….

For more on wireless power applications please contact us.

A product oriented demonstration

[9] The impedance adapters only need to be reversed as capacitive dipole involve much larger impedances than inductive ones.

7 - Safety

Kantanlabs products are totally safe if used properly. The experimenter cannot be seriously harmed as the amount of energy stored in each alternation is extremely small. The current involved are so small and the frequency so large, that the tiny part[10] of the current that may cross the muscles of experimenters or active participants do not even lead to any muscle contraction or other harmful effects.

In most cases you will hardly fill anything even in case of direct contact. In the worst cases, if input power is raised up to several watts and a focused spark is maintained for a long time[11], minor local skin burning may result and will self-heal in a few days.

However, as High-voltage could lead to ionization, it is highly recommended to avoid the use of any flammable material in the vicinity of high-voltage equipments. Note that initiating combustion of most flammable material will be hard to reach with the low energies stored in KantanLabs products except perhaps for materials with a very low thermal threshold.

[10] The current do not penetrate deeply inside human tissues because of the skin effect.

[11] In most cases when you fully touch the electrodes, the voltage drops because of the detuning effect of a large added capacitance to ground (compared to the usual values involved in our experiments) and the power allowed to flow in your body is extremely small. To maintain a breakdown channel between a high-voltage electrode and your finger leading to some thermal effects, you have to adjust accurately the gap between your finger and the electrode.