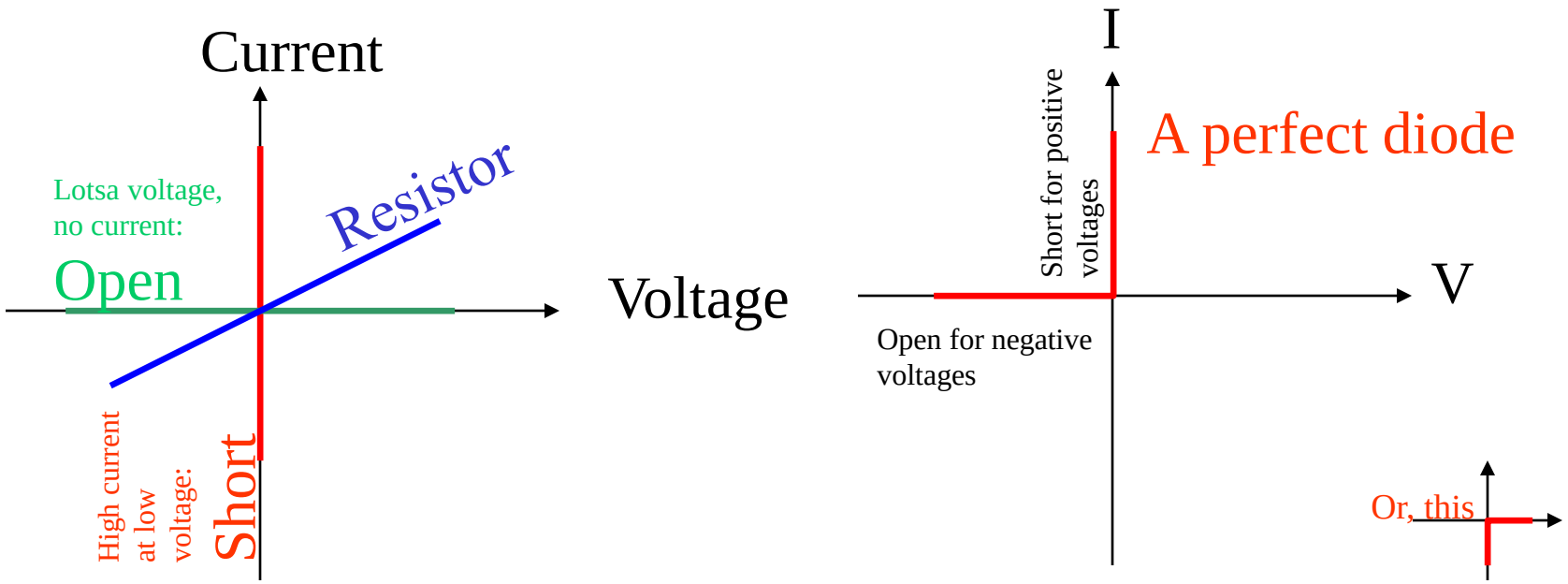
Fox-Hole Radios:
Mineral Detectors vs. Diodes

Gord Rabjohn

Overview

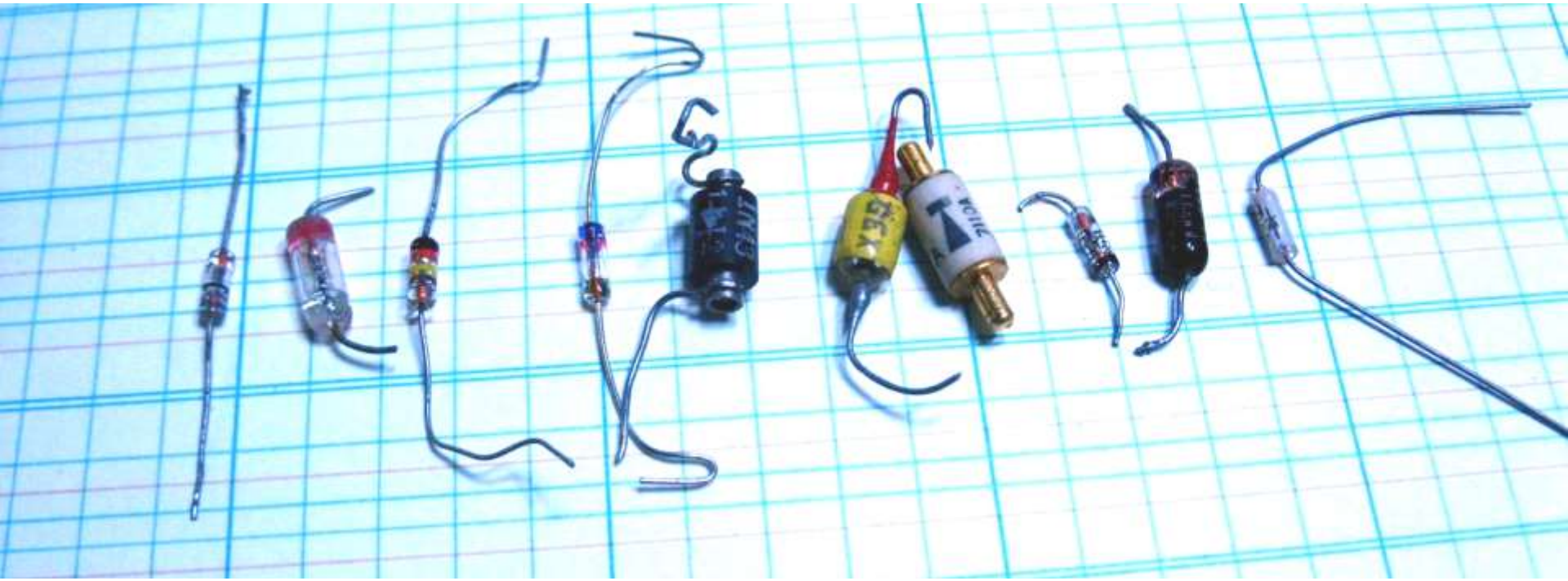
- I-V curves of various diodes and junctions
- Performance in a radio test bed
- Performance in a “fox-hole” radio

I-V curves


Current
Voltage
Lotsa voltage,
no current:
Open
Resistor
High current
at low
voltage:
Short
I
V
Short for positive
voltages
A perfect diode
Open for negative
voltages
Or, this

Curve Tracer

Germanium Diodes

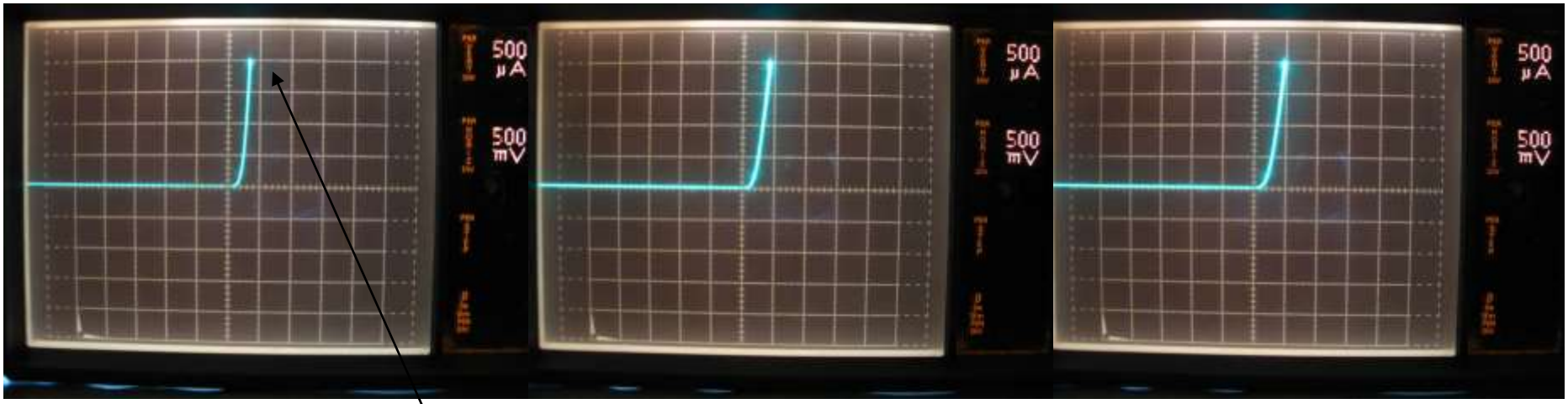


Germanium Diodes, 1N34A etc.

My Favorite 1N34 (ITT)

Cruddy 1N60

A standard banded 1N34A



This diode has lowest voltage here

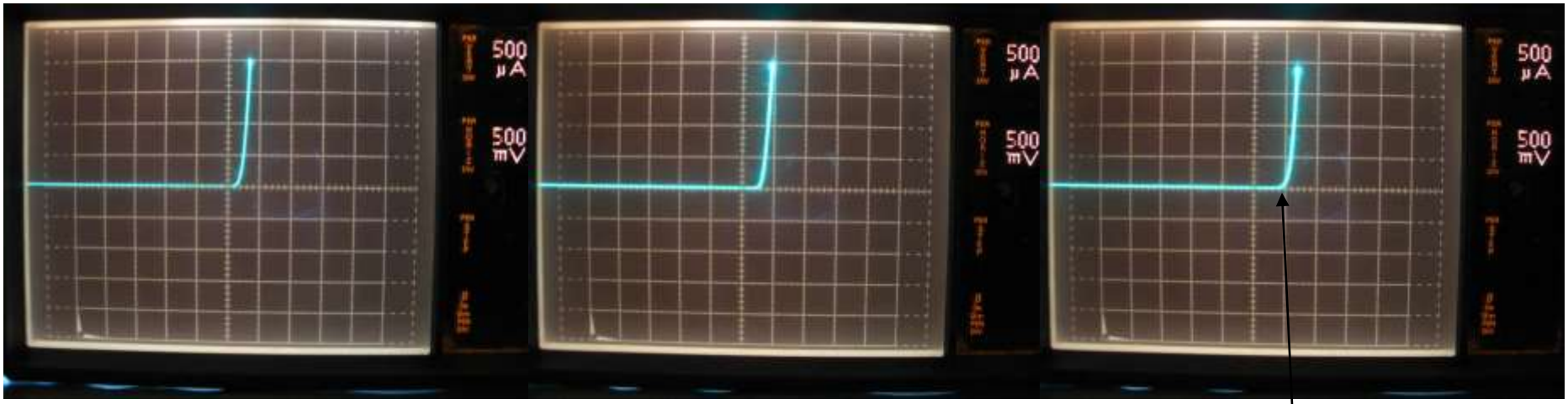
Notice:

Low leakage

Turns on in under 0.3V

Silicon Diodes

My Favorite 1N34 (ITT) 1N5711 (Silicon Schottky) Standard 1N914 (Silicon)



Low barrier, but turns on later than germanium

No action until ~0.5V

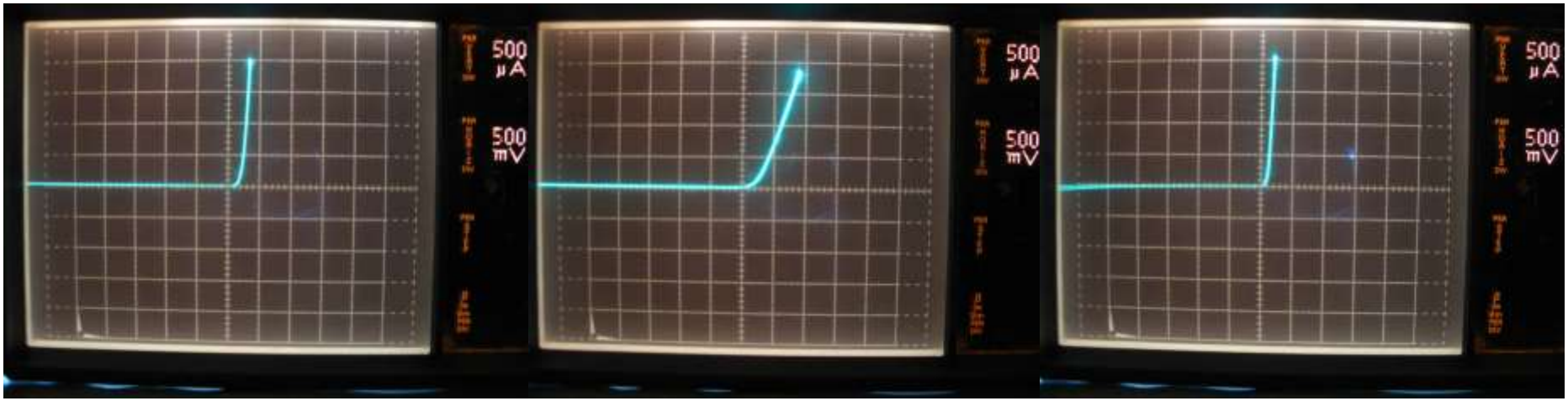
A Glass Diode

Other diodes

My Favorite 1N34 (ITT)

6AL5 tube

Custom GaAs diode



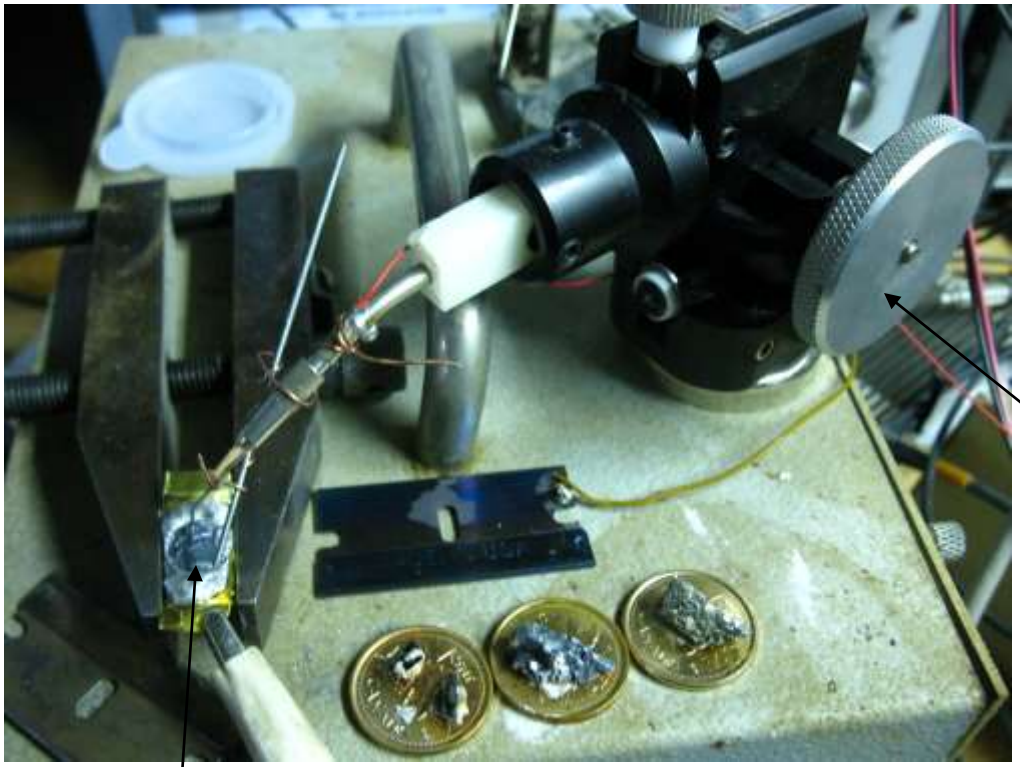
Much slower turn-on

A GaAs diode not commercially available.

Galena

Lead Sulfide, PbS (pronounced g*uh*-lee-n*uh*)

Galena



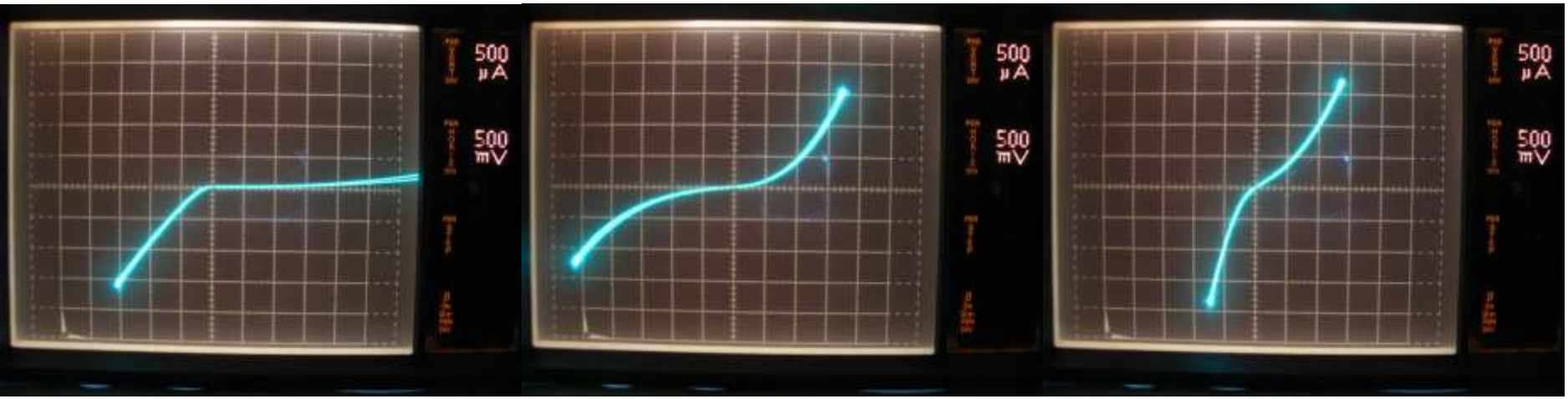
X-Y-Z manipulator

Galena mounted in solder

Galena Diodes

By best piece of galena
with metal cats whisker

Other lumps of galena



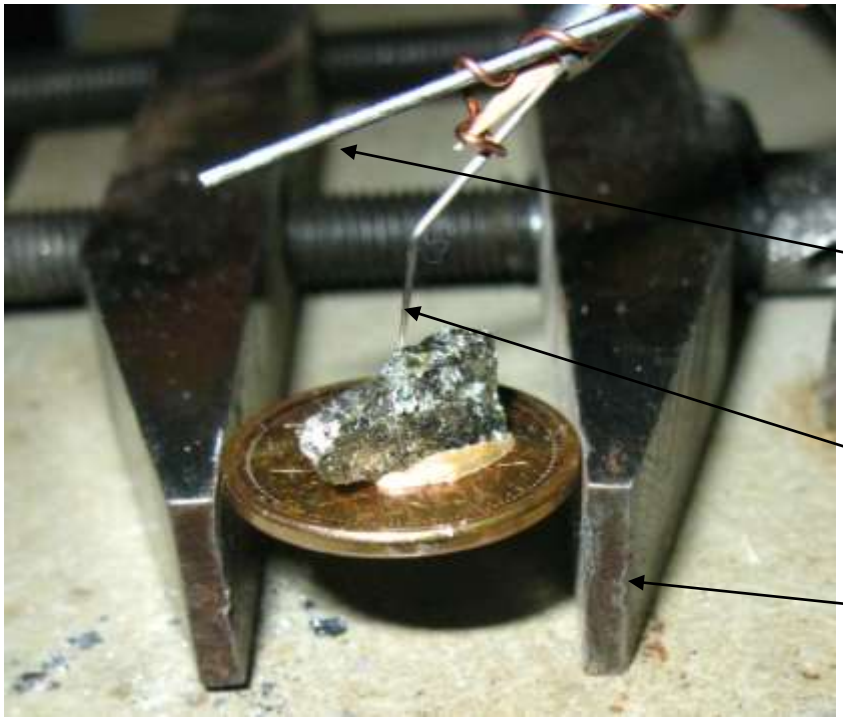
Positive connected to whisker

The best galena (the best not-prefabricated diode) was a sample I received when I was about 10 years old. It is sensitive all over and produces very nice I-V curves in most spots. The other lumps of galena were not as good.

Pyrite

Iron Disulfide FeS_2, (Fools Gold)

Pyrite



Graphite (pencil lead) also tried

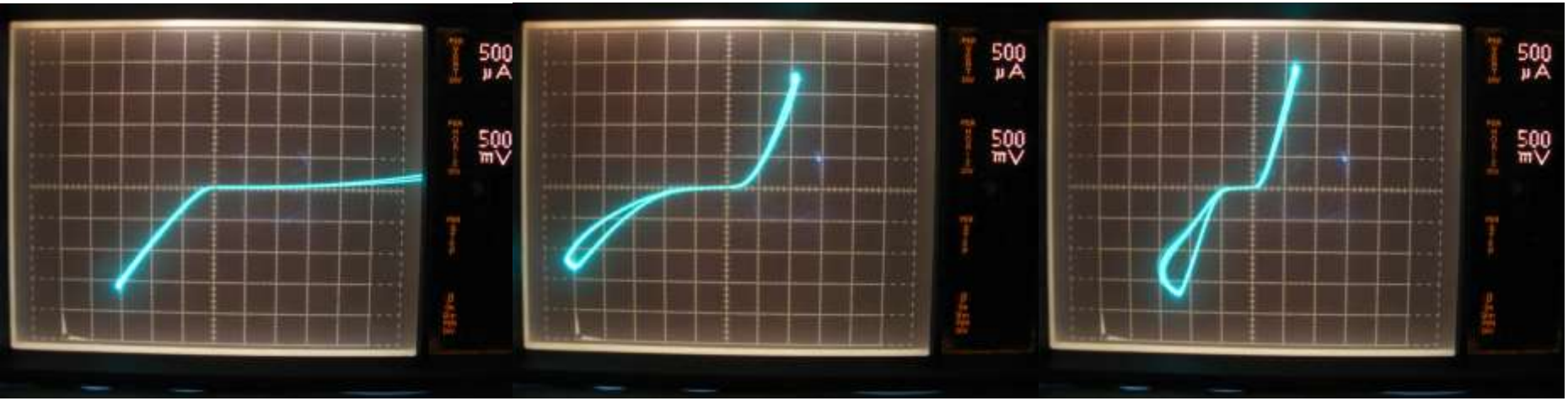
Metal probe needle (beryllium copper?)

Clamp that holds sample

Pyrite Diodes

By best piece of Galena with metal cats whisker

Iron Pyrite. Similar results clamped, or silver epoxy



It was fairly easy to make a poor non-linear contact, but tough to make a really good one

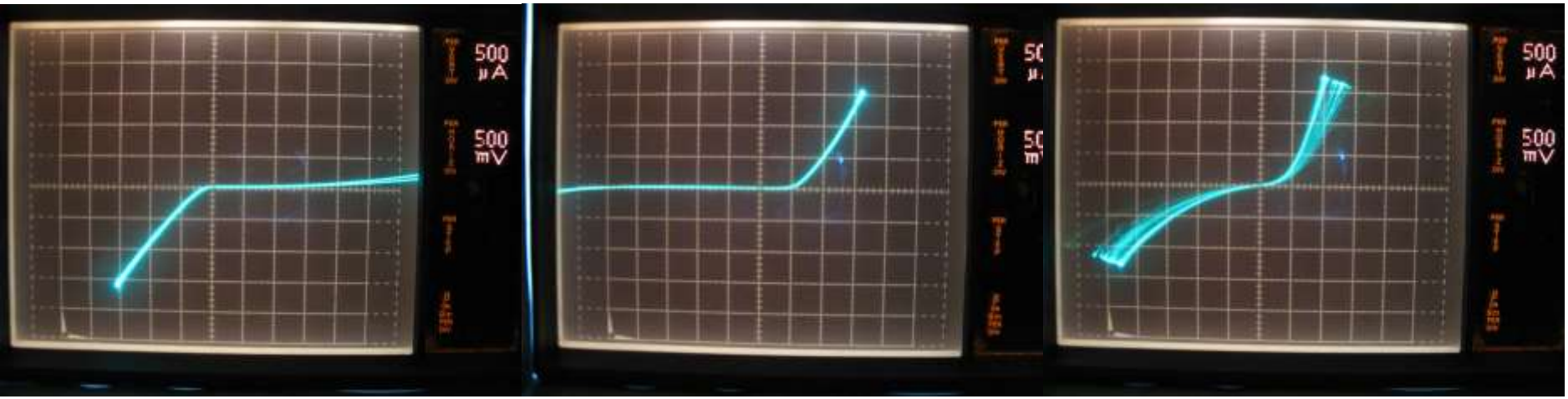
Positive connected to whisker

Germanium Chunks

Germanium Chunk Diodes

By best piece of Galena with metal cats whisker

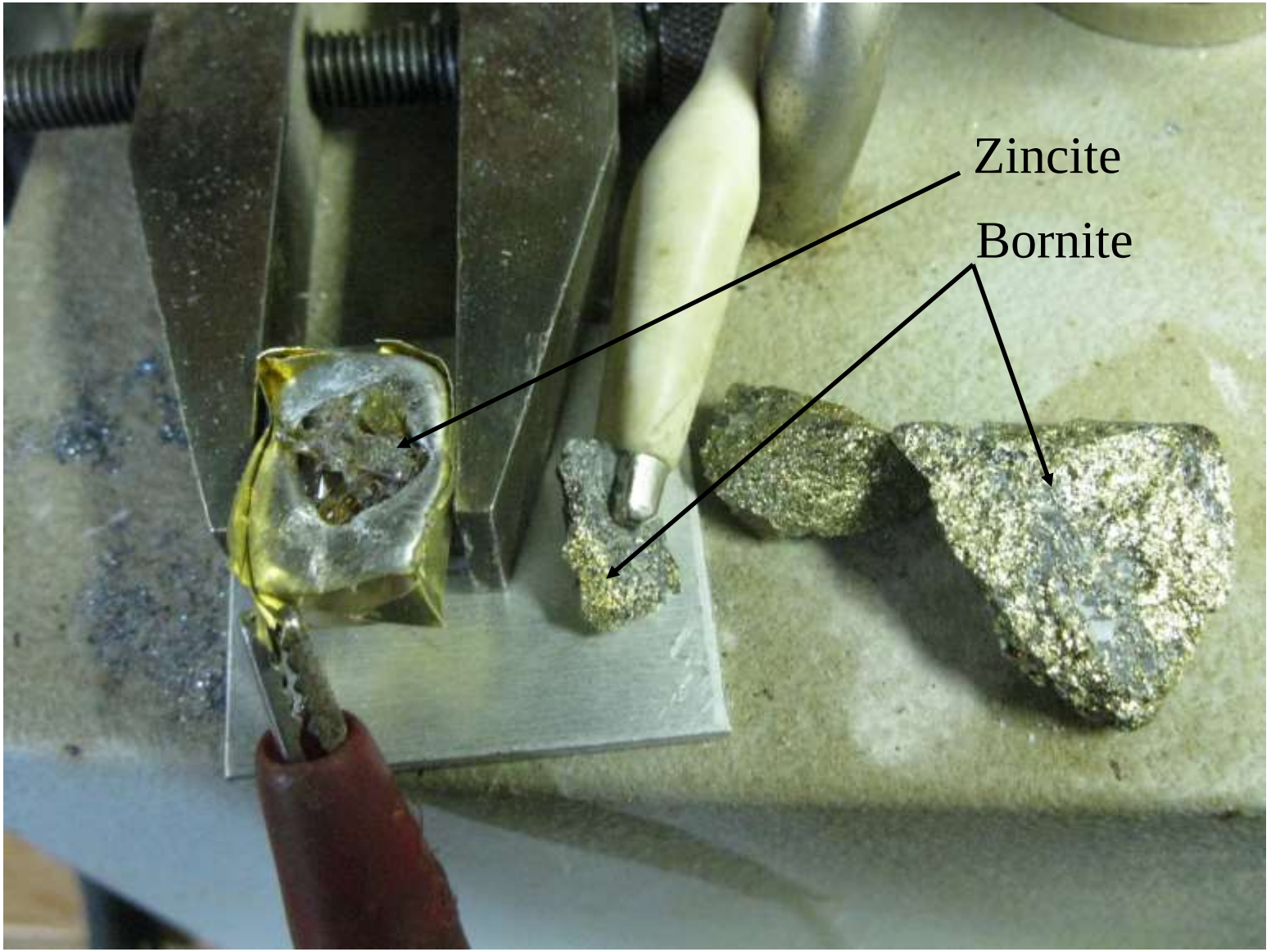
Germanium mounted on a coin



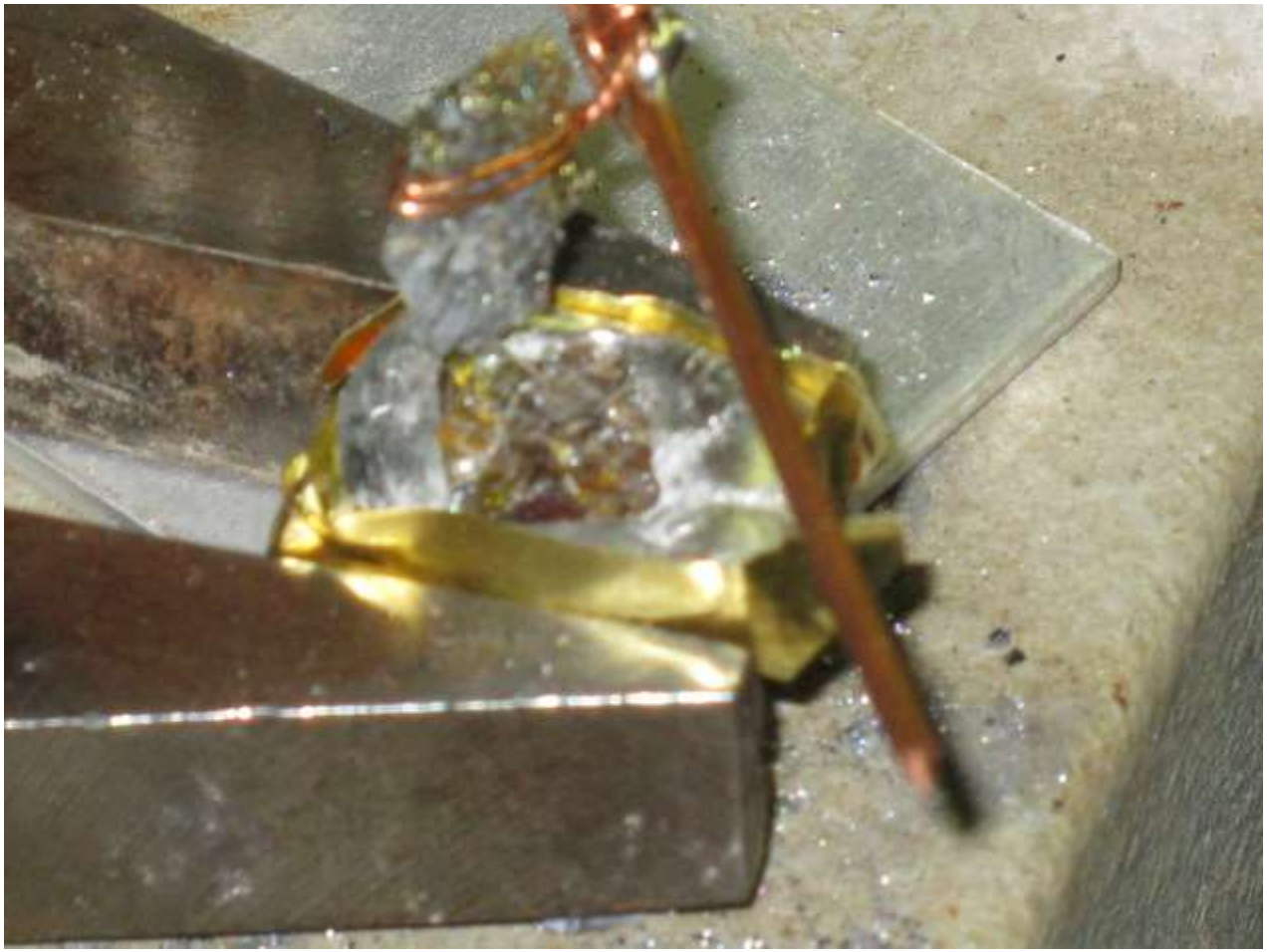
Note generally good leakage current, but rather high turn-on voltage.

I tried making an “Alloy junction” diode by melting a piece of indium into the germanium. The result was a short circuit. The nature of the germanium was unknown, maybe not appropriate for an alloy junction.

Pericon



Poor Pericon Picture



Pericon

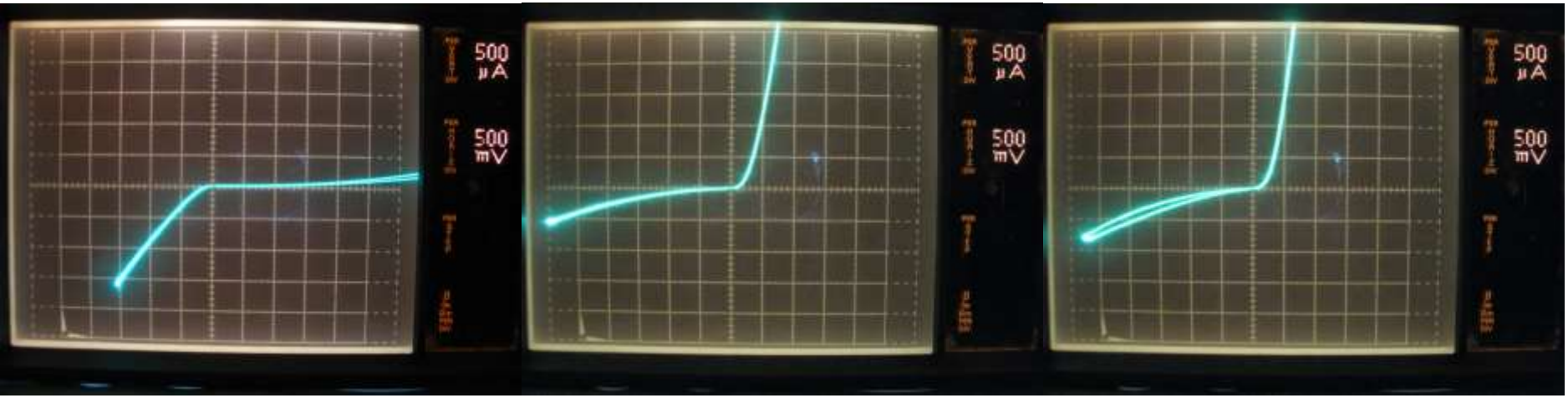
- A crystal-to-crystal contact
- Zincite: ZnO Fairly rare, except for New Jersey. Mine was from Franklin, New Jersey, and a chimney in Poland. My sample appeared mostly transparent (therefore probably insulating), bit one small spot was very active.
- Bornite: Cu_5FeS_4 Active all over.
- A similar material can be used instead of Bornite: Chalcopyrite $CuFeS_2$
- I found that Zincite with a cats whisker was also a reasonable detector.

“Pericon Detector”

By best piece of Galena with metal cats whisker

Forward biased when boronite is positive.

Pericon

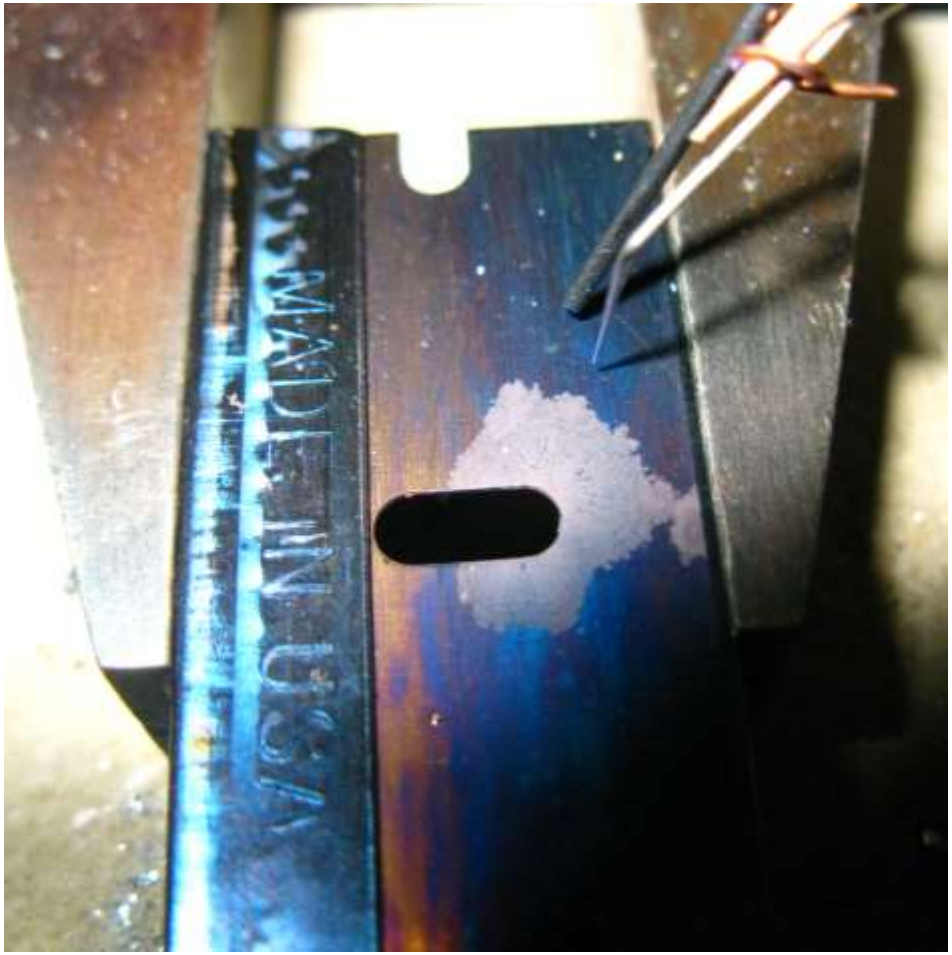


Only a few sensitive spots were found on the zincite (most of the crystal was an open circuit), but the spots that *were* there gave nice I-V curves; low turn-on, low resistance.

Razor Blade Detectors

• By heating a razor blade on the stove, I could get a beautiful blue oxide growth. (The modern Gillette blades are *painted* blue) The bit of rust in the middle can't hurt.
• I also did one with a blow torch, warming the blade until it turned red. This produced a gray colour.

Razor Blade Detectors



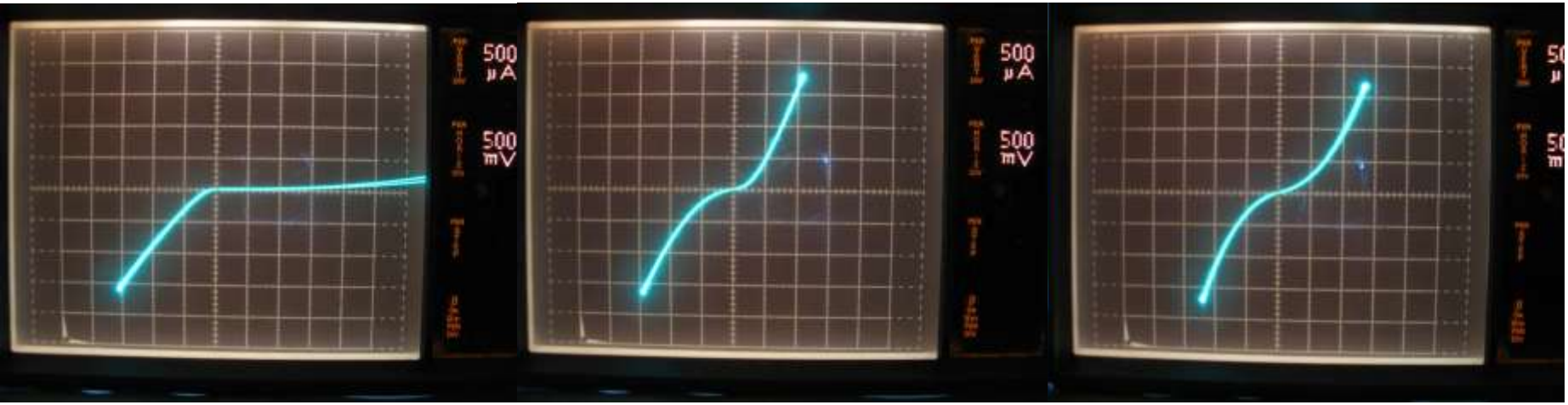
Choice of graphite or metal point

Razor Blade Detectors

By best piece of Galena with metal cats whisker

Not blued, metal point contact

Not blued, graphite contact



Positive connected to whisker

Tend to get a non-linear curve, but symmetrical (which produces no detected voltage).

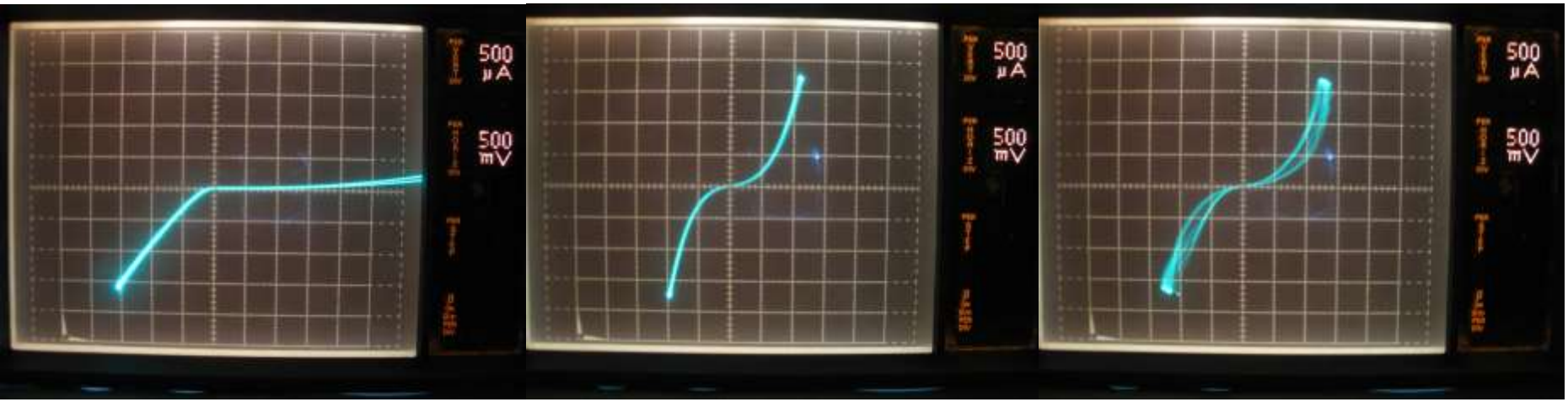
Graphite more forgiving, but metal point, with care, made a better diode.

Razor Blade Detectors

By best piece of Galena with metal cats whisker

Blued, metal point contact

Blued, graphite contact



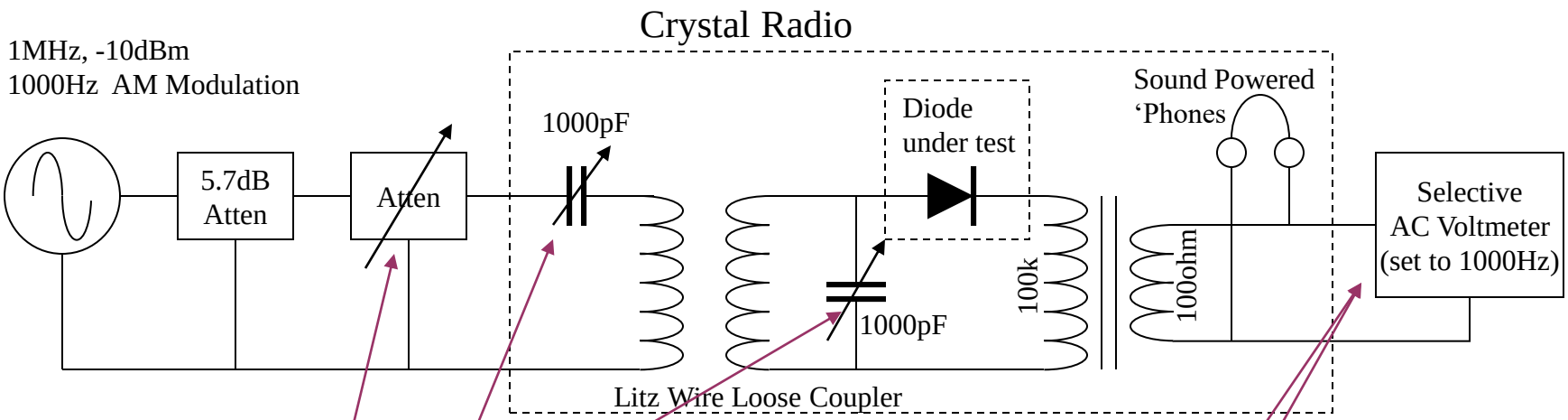
Positive connected to whisker

The blued metal was not remarkably better than the clean metal.

RF Performance

- Frankly, I've wasted your time. Curves do not tell us much about the ability of a detector.
- According to Tongue, leakage is important, as well as what happens in a few uA around the origin. These can not be seen easily on this type of curve trace.
- What really matters is how well the detector picks up weak signals.

Diode Test Apparatus



Capacitors are adjusted for peak audio output.
Attenuator is adjusted for 30uV audio output.


1007 Hz

Diode Sensitivities

Test Case	Power*
My favorite “ITT” germanium diode, room temp.	-59.1dBm
My favorite “ITT” germanium diode, warm	worse
1N5711 silicon schottky diode, room temp	-53
1N5711 silicon schottky diode, ~45C	-59.3
1N914 silicon diode, room temp	-46.7
1N914 silicon diode, ~55C	-53.5
6AL5 (running at 6.3V on filament)	-54.5
6AL5 (running at 5.1V on filament)	-55.8
Run-of-the-mill Ge diodes	-55 to -57
2SB175 Germanium transistor	-49
CK722 Germanium transistor	-42.5
Custom low-barrier GaAs E-mode diode-connected FET	-60

* Power required for 30uV into headset (barely audible)

Results

- The best detector was “My favorite” ITT germanium diode.
- Silicon schottky, if warmed up to reduce the turn-on voltage, was as good.
- Custom GaAs diode was best, but unobtainable.
- Most germanium diodes were pretty good, but ~3dB shy of the best parts.
- I was surprised that the tube wants to be run at a low filament voltage for best performance.

Sensitivity of Improvised Detectors

Test Case	Power*
(Best diode from last slide)	-59 to –60 dBm
My favorite galena crystal	-57
Metal point on germanium	-49
Graphite on rusty blade	-40?
Iron Pyrite	-48
Pericon	-53
Metal point on blued blade	-44?
Graphite on blued blade	-40?
Graphite on galena mounted in lead	-50
Germanium chunk	-48

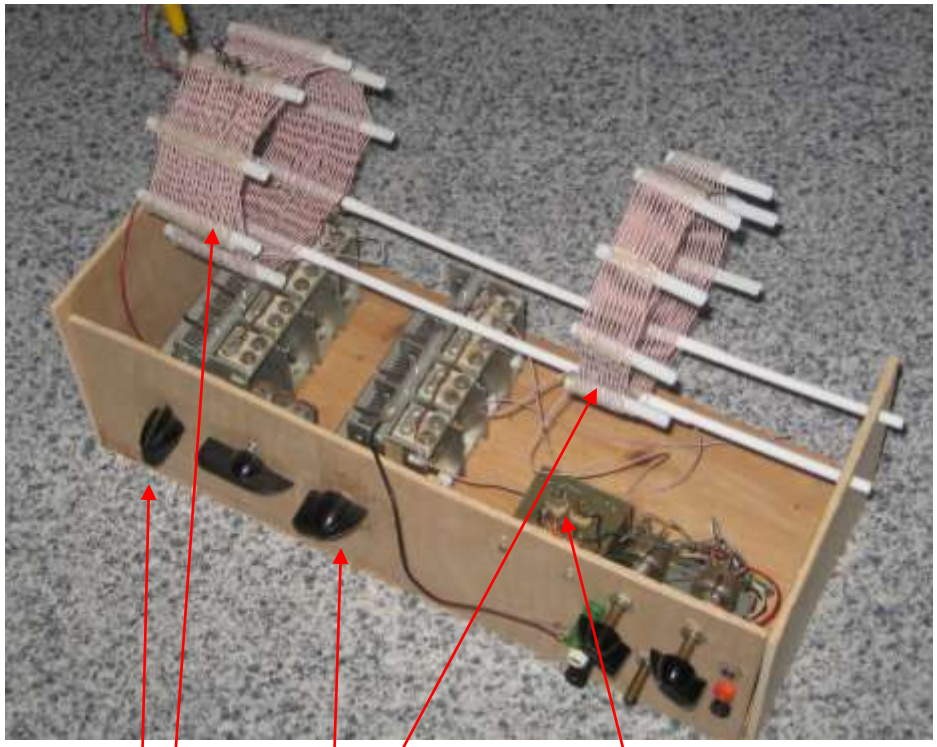
These numbers are all very approximate because of the nature of the point contact

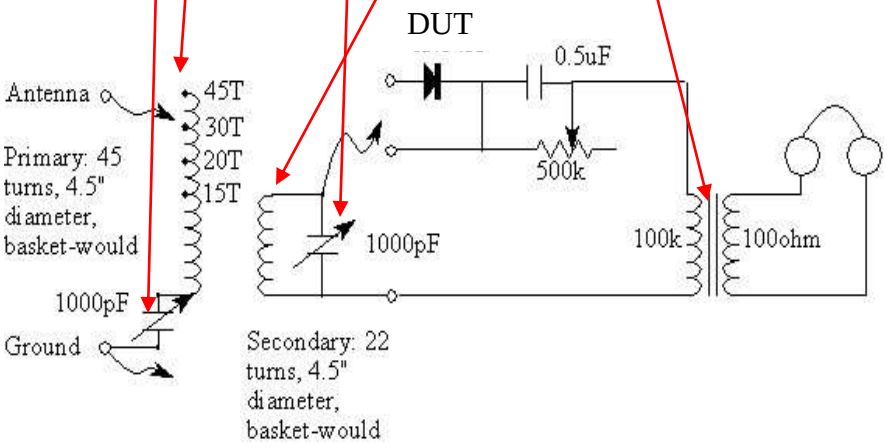
* Power required for 30uV into headset (barely audible)

Improvised Detectors

- My mounted galena was the easiest and best detector. Surprisingly, as good or better than most germanium diodes!
- Pyrite and Pericon was next easiest to make a detector with. Pericon very robust.
- The other galena samples were not as good; tougher to find a good spot. (was my mounted galena treated? Or just well selected?)
- Blade was toughest. Graphite (pencil lead) contact made best diode for me. Very touchy, very weak.
- But all samples worked in the loose coupler based crystal radio.

Crystal radio



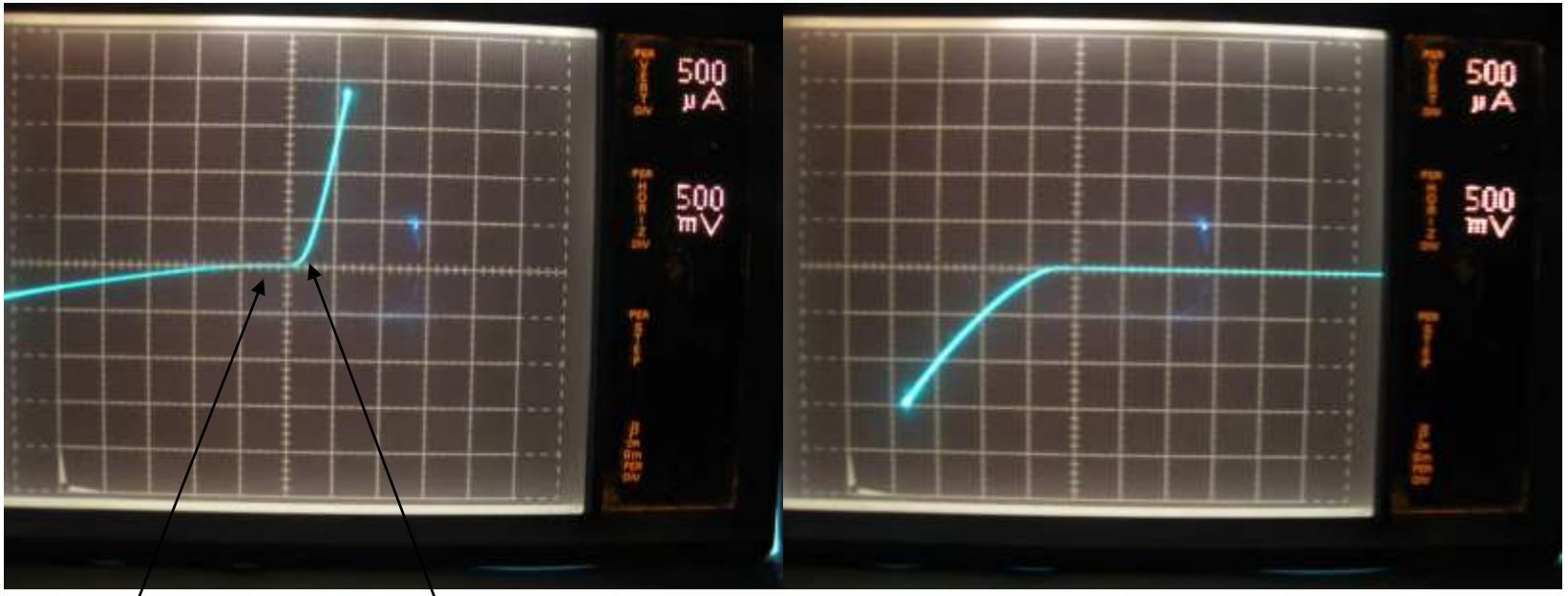


- ~70 foot external antenna
- Litz wire basket wound with taps for experimentation.
- Ceramic insulated variable capacitors for maximum Q
- Sound powered headphones

Using mineral detectors in a tuned crystal radio

- All samples worked fine on local stations
- “My favorite galena” made a reliable sensitive detector. Got WBBM 780kHz Chicago at comfortable volume.
- Pyrite made a respectable detector. Got WLW 700kHz Cincinnati and WCBS 880kHz New York at comfortable volume.
- Pericon worked well in the “good” area, and is not as touchy as other detectors.
- Razor blade + graphite was a struggle. However, I was able to get WHAS 840kHz Louisville Kentucky!!! (very very faint, and I was very very lucky!)
- Adding 0.5V bias in series with the blade + metal needle made a *huge* improvement, making it viable. Received WCBS and WABC, New York with good volume. Still quite touchy, but sensitive when a good spot is found.

Winning curve traces



Low close-in leakage

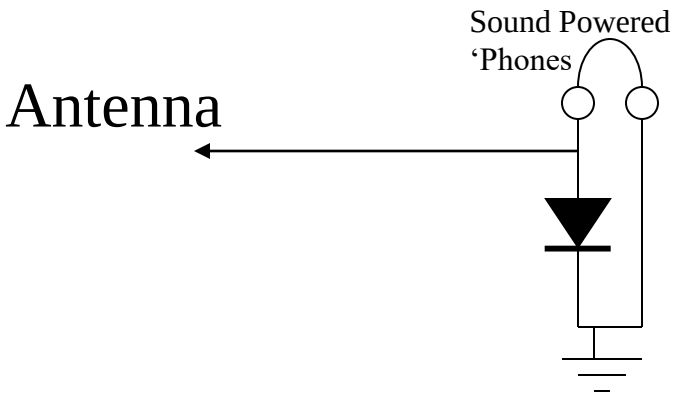
Low voltage knee

New York Pyrite

Chicago Galena

"The blade" was too unstable for a curve trace. In fact, running a curve trace always ruined the detector.

Fox Hole Radio



Fox Hole Radio Results

- All devices I tested worked in a “Fox hole” radio configuration.
- Of course, they received the 3 local stations at once, however, they were a comfortable headphone volume.
- The guys in the fox hole must have had a good antenna, and more patience than me!