A Collection of Interesting Coating Challenges (and Solutions!)

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A collection of interesting vacuum-coating challenges will be presented, from uniformly coating small glass spheres to roll-to-roll coating paper, along with the solutions implemented.

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A Collection of Interesting Coating Challenges (and Solutions!)

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A brief introduction:

- Honours B.Sc., Modern Physics, University of Waterloo
- Condensed Masters, Modern Optics, University of Rochester
- 94 US Patents
- A few things I have designed or created:
  - **Nuclear reactor cores**
  - One-man submarine life support
  - **Optical coating design program**
  - Optical raytracing program
  - **Helicopter landing system**
  - Glass bottle inspection equipment
  - Industrial cameras
  - Nanostructures w/femtosecond laser
  - Utility-scale solar collectors
  - Cell-phone cameras
  - "Just-Walk-Out" cameras
  - Compact Lidar for delivery robots
  - Health band
  - VR Goggles (eye-tracking system)

Why am I here:

Vivek and I work together at Meta. He is a Manager of New Technology in our VR labs and I am a tech lead for eye tracking.

Vivek is also one of our lead coating engineers and very active in the SVC.

One day over lunch I related some of my coating stories to Vivek. He enjoyed them and thought that you might too. I hope that you like these stories as much as Vivek did. These stories have nothing to with Meta.

Meta

Vivek Gupta

Leo Baldwin

Gold-coated glass beads

Ontario Research Foundation

1978

Bob Bertram, Ed Faber, myself

Contract research for government and industry.

I worked in the Physics Lab, mostly vacuum coatings, testing solar collectors, and refining and doping semiconductors.

Sheridan Science and Technology Park
Mississauga, Ontario, Canada

Gold-coated glass beads

Atomic Energy of Canada (AECL) approached us to create a fairly large batch of 3mm glass beads uniformly coated with 200Å of gold.

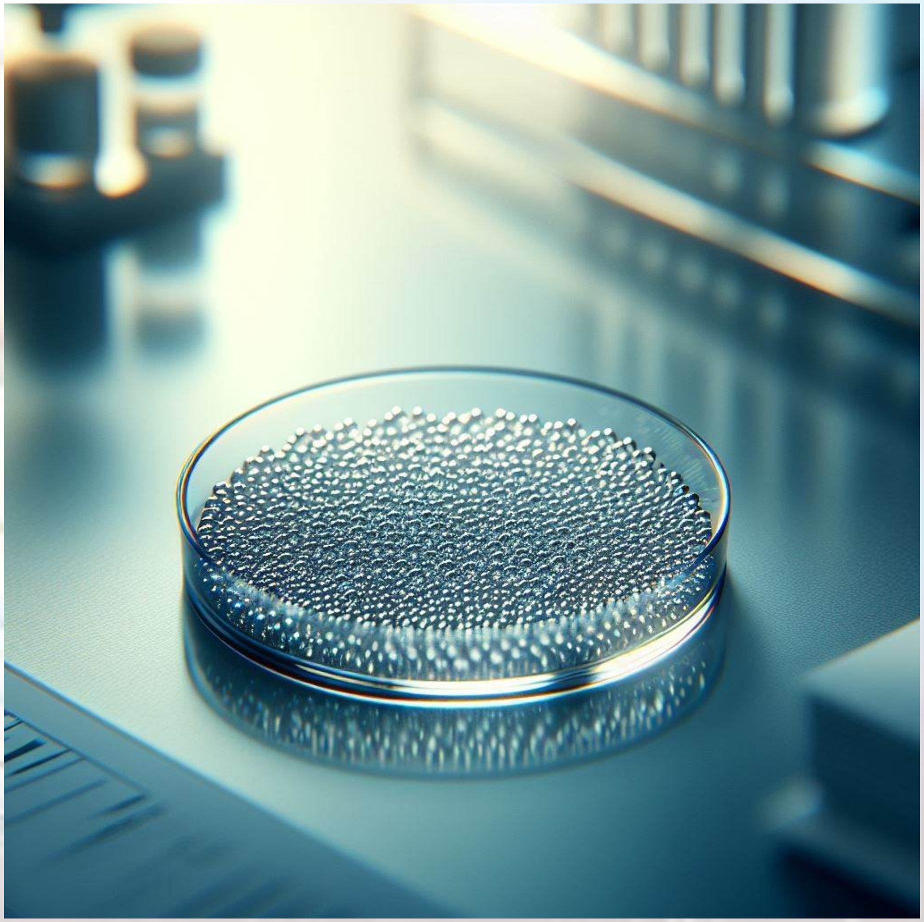
How to do this fairly cheaply and quickly with minimal tooling expense?

Gold-coated glass beads

Putting the glass beads in a petri dish and vibrating the glass dish to make the beads dance during the coating process.

If the motion is sufficiently vigorous and random, the coating will be uniform.

But will scuffing be a problem (gold is soft after all)?

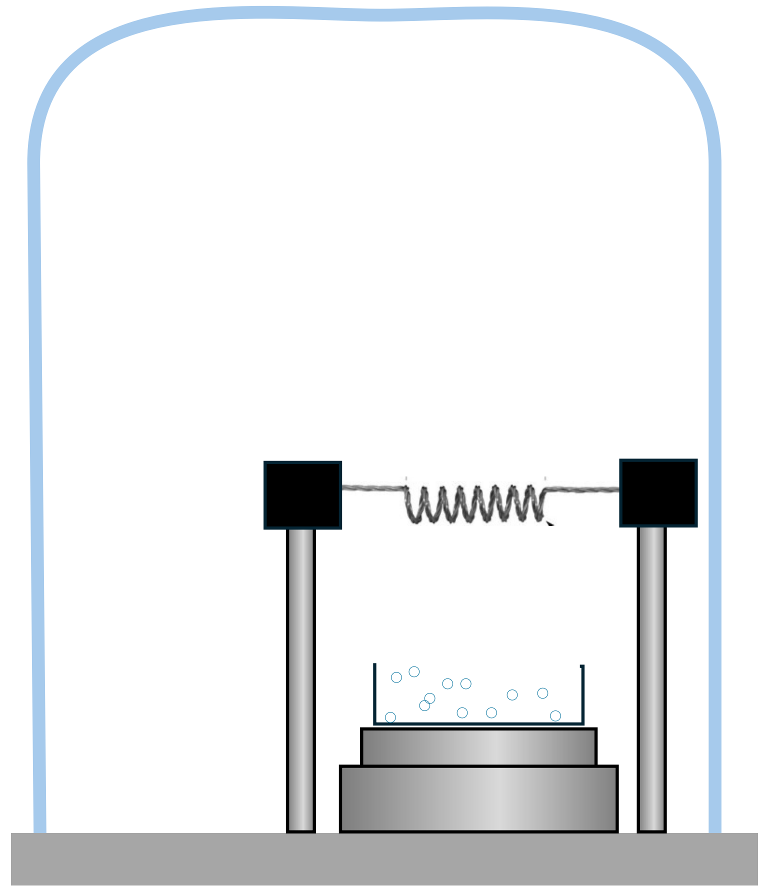


Gold-coated glass beads

First test:

A tungsten source over the petri dish, the dish vibrated until all of the beads were “dancing”.

Good:
Coating is uniform and undamaged
Bad:
Difficult to control thickness

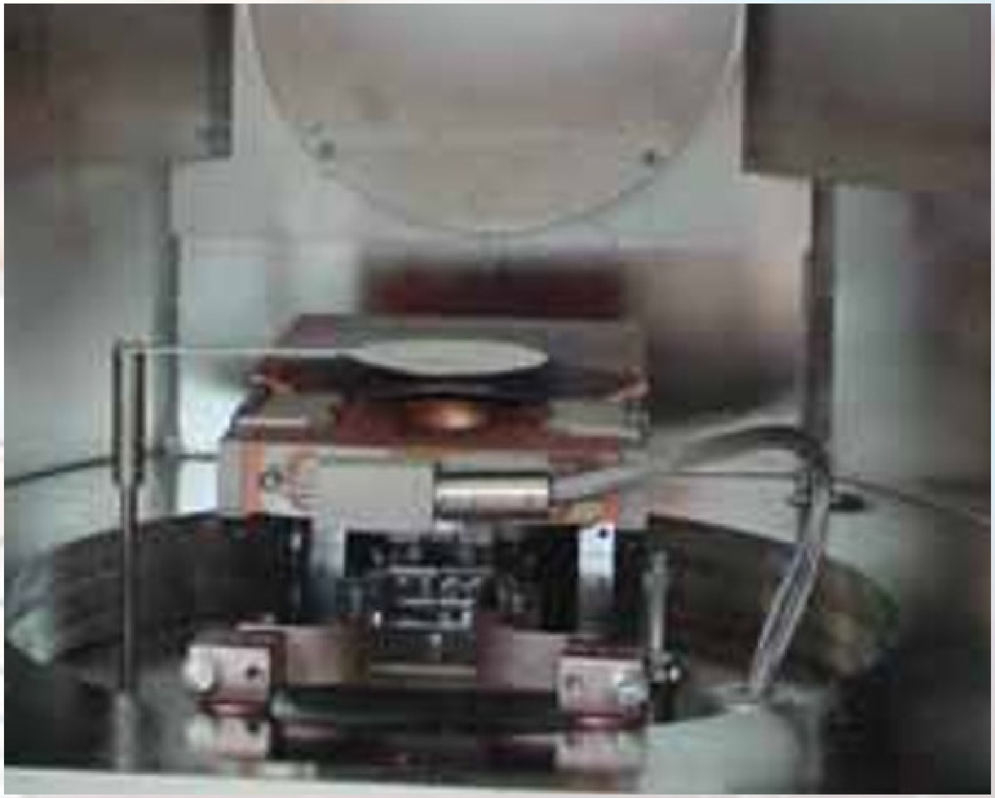


Gold-coated glass beads

We want to use our e-beam source with shutter for a more uniform evaporation rate with precise control of cut-off.

But…e-beam source evaporates up, and we are using gravity to keep our beads in the petri dish.

What to do……

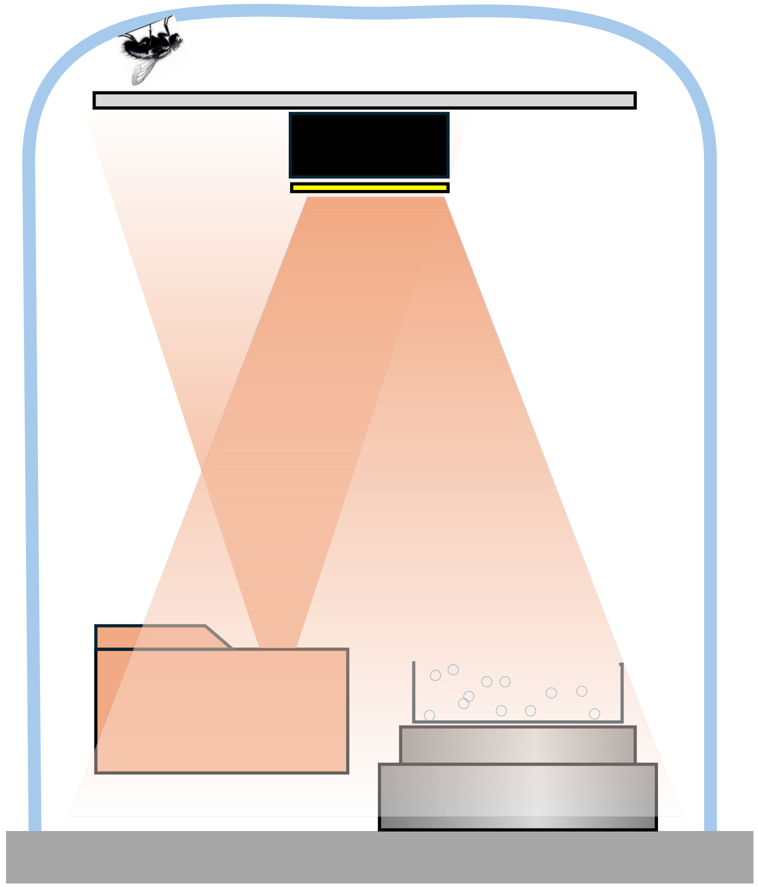


Gold-coated glass beads

Solution:

Reflect some of the gold atoms ejected from the source with a (very) hot mirror.

Platinum foil (so that we didn't plate the mirror material along with our gold) induction heated from behind.



Gold-coated glass beads

Side story: the fly

Recall the movie “The Fly”, where a fly gets into the teleportation chamber with Seth Brundle (Jeff Goldblum). As a result their DNA gets merged and Seth slowly turns into Seth Brudlefly.

We had our own fly in the chamber

Gold-coated glass beads

Side story: the fly

The fly survived pumping down to 10-7 Torr, gold deposition, and bringing the chamber back to 1 ATM on dry nitrogen before flying away!

The fly was fully gold-plated on the top side and flew around the lab for a couple of weeks before disappearing.

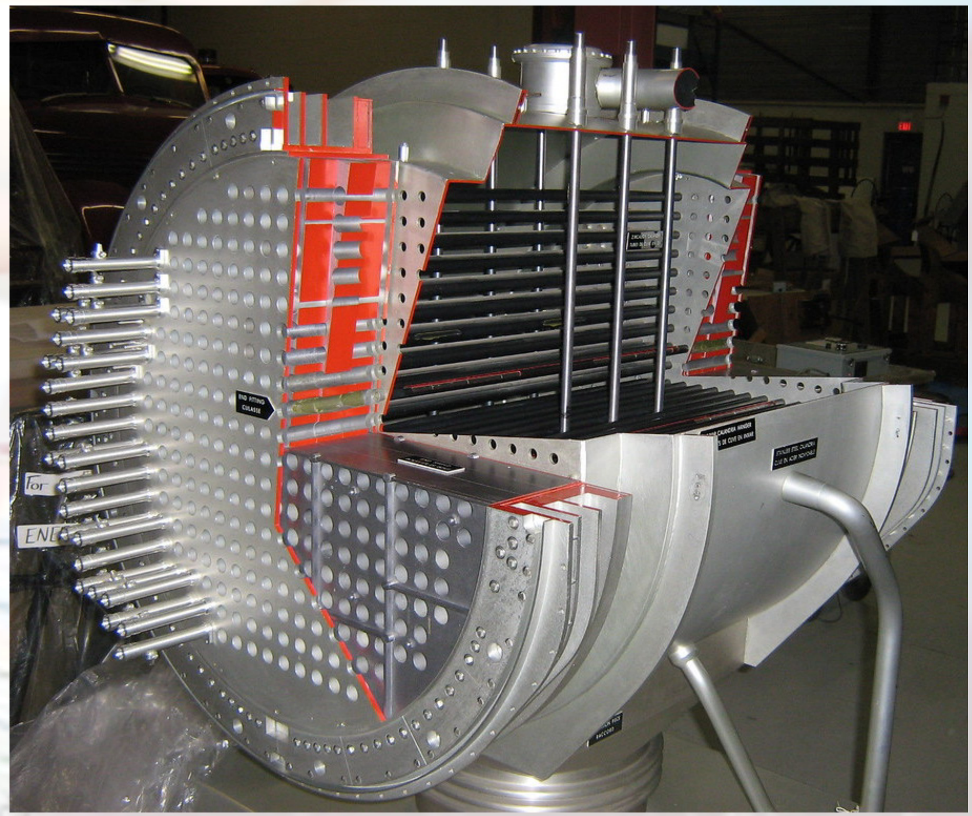
Gold-coated glass beads

Side story: the gold beads

What does AECL want with glass beads?

They never told us, but about 6 months later I was working there designing reactor cores, specifically the adjuster rods.

Note the red area on the end caps.

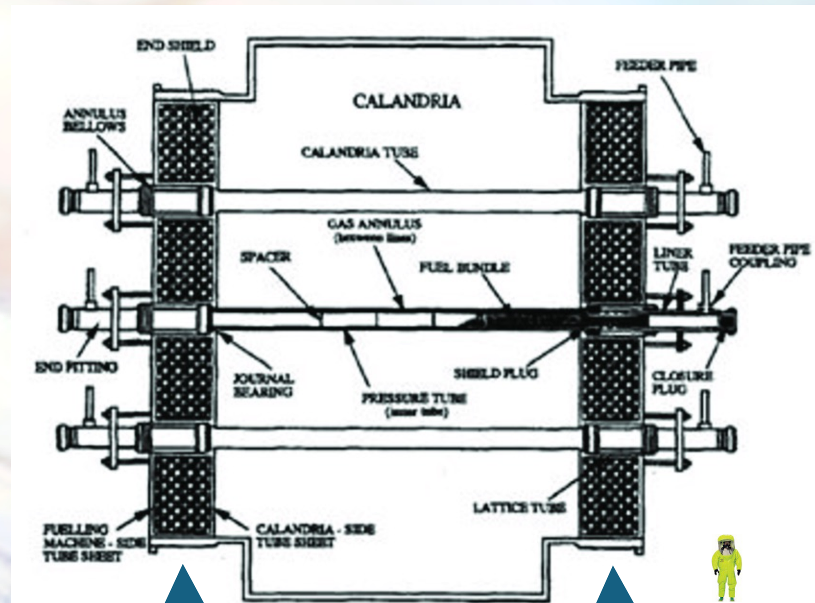


Gold-coated glass beads

Side story: the gold beads

Those end shields are filled with steel ball bearings.

Neutrons behave a lot like photons. I suspect that AECL was using the gold-coated glass beads and light to model the steel ball bearings and neutrons. (I never confirmed this).



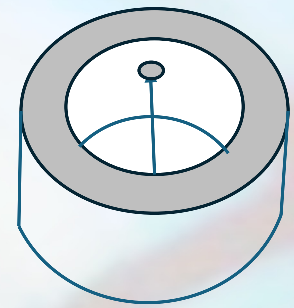
ball bearings

Capacitors for an accelerometer

In 1978 we were helping Bell Aerospace make an accelerometer that had a measurement range of 1ug to 450g.

It used a nickel weight on the end of a nickel whisker bending beam. The position of the bob was measured with 3 capacitors in the plane of the bob.

The 3 capacitive sense elements were vacuum deposited (SiO_2 and Ni).



Capacitors for an accelerometer

We couldn't get past the dreaded mil-spec Scotch tape peel test. I suggested we bypass that test and go to annealing.

After annealing, we easily passed the tape peel test, abrasion (with a pink eraser), and all of the other tests.

Writing programs and coating paper

Optikon

Minas Vasiliadis

NRC

Jerzy Dobrowalski

Interoptics

Jeff Wimperis

Leo Baldwin

Sue (Piotrowski) McCall

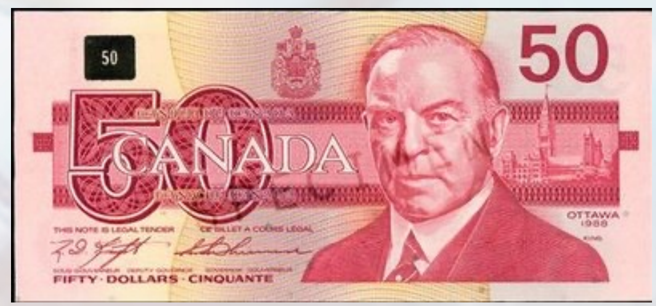
4.77Mhz 8088 64KB

Writing programs and coating paper

I had a small issue writing my coating design program for Jeff, so he sent me over to George (Jerzy) for a little help.

Embarrassingly, it was a stupid matrix-indexing mistake (i,i) instead of (i,j) but I got to meet George and hang out and hear some great stories.

One was about money

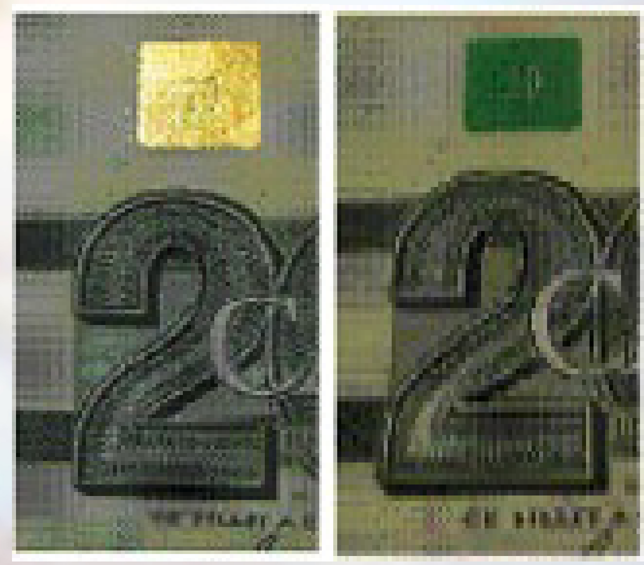


Writing programs and coating paper

To help out the Canadian Banknote Company (“Mint”) , George developed an anticounterfeiting device for paper currency: an optical dielectric coating.

The coating would change color dramatically with angle. It was robust, obvious, and difficult to replicate.

But for me, the fascinating part was the paper handling.

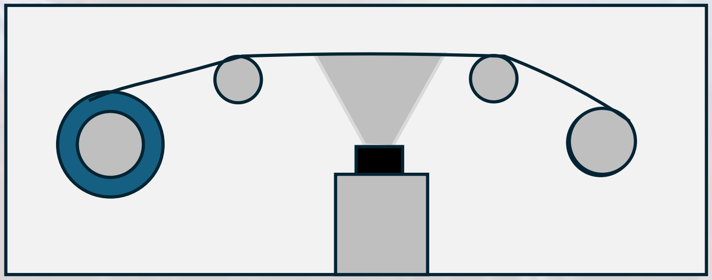


Writing programs and coating paper

Conventional wisdom dictates that you load your rolls into the vacuum chamber, with a supply spool and a take-up spool.

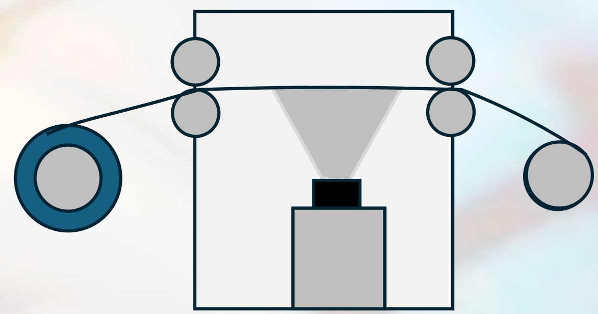
I did the same at ORF when I roll-coated some polyester film with various metals (gold, silver, aluminum, chrome, nickel) to see which one would make the best IR insulator.

Sure, you could just look in the IR Handbook, but that is not how grants work.



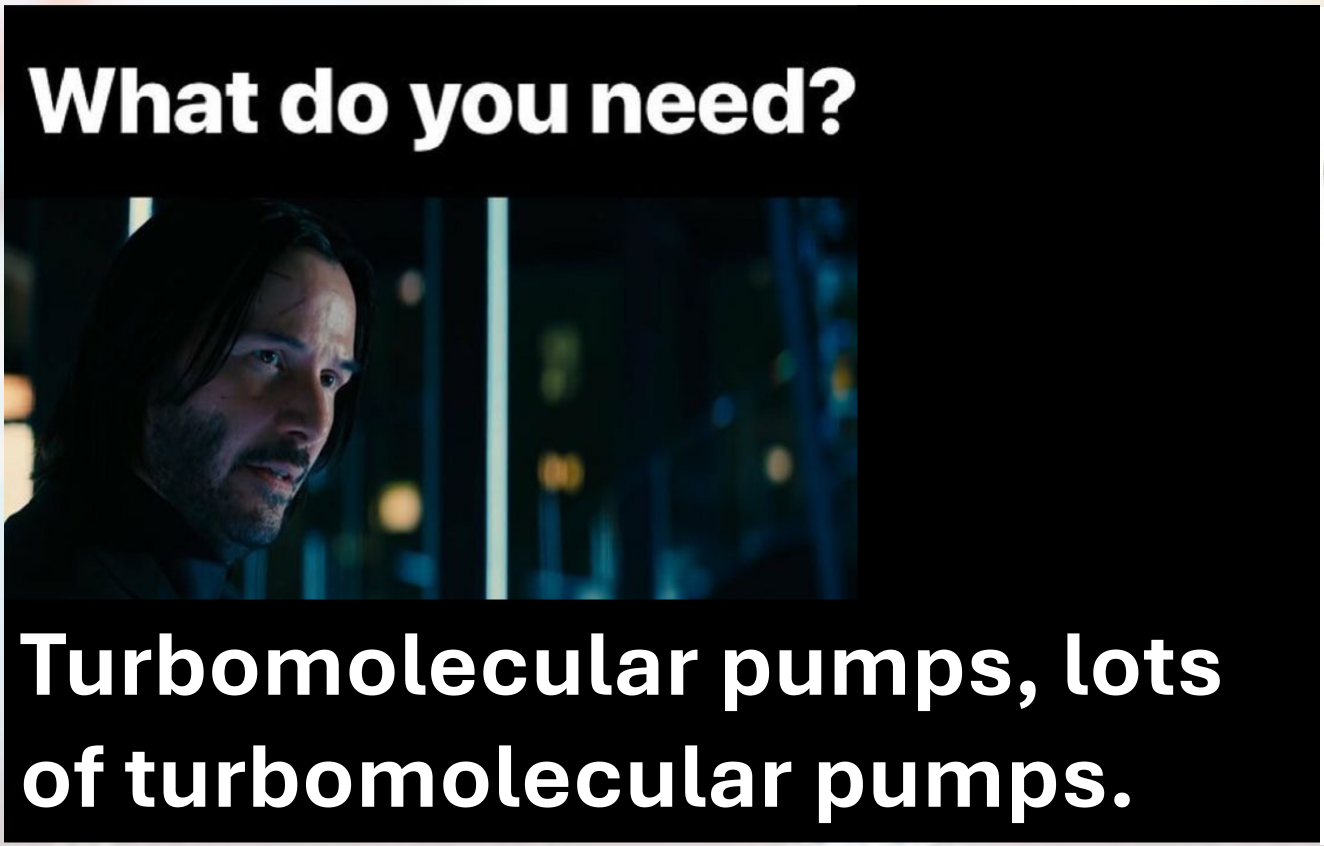
Writing programs and coating paper

But that would be too slow, loading rolls of paper, pumping down, coating a roll, bringing the chamber up to atmosphere, unloading the coated roll and repeating.



George put the rolls outside the coating chamber. So not only was he outgassing paper, he was pumping against two giant leaks (the rollers "sealing" the paper entry and exit). How to cope with that?

Writing programs and coating paper

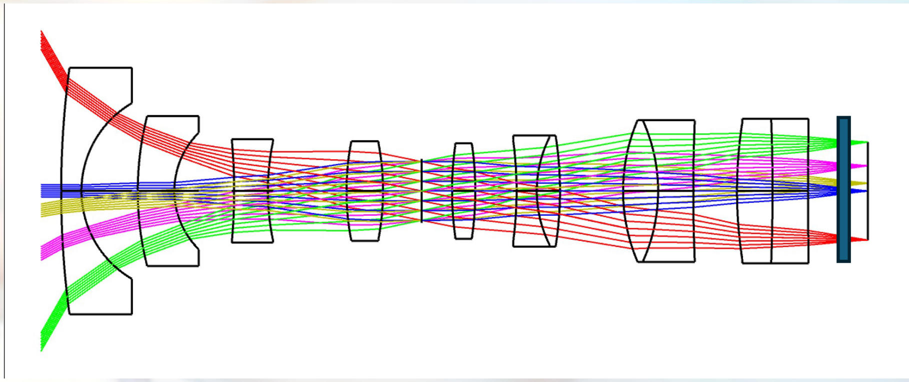


Landing helicopters on ship deck

In 1990 I moved to Indal where I ended up redesigning the beacons, cameras, and software for a helicopter landing system.

Landing helicopters on ship deck

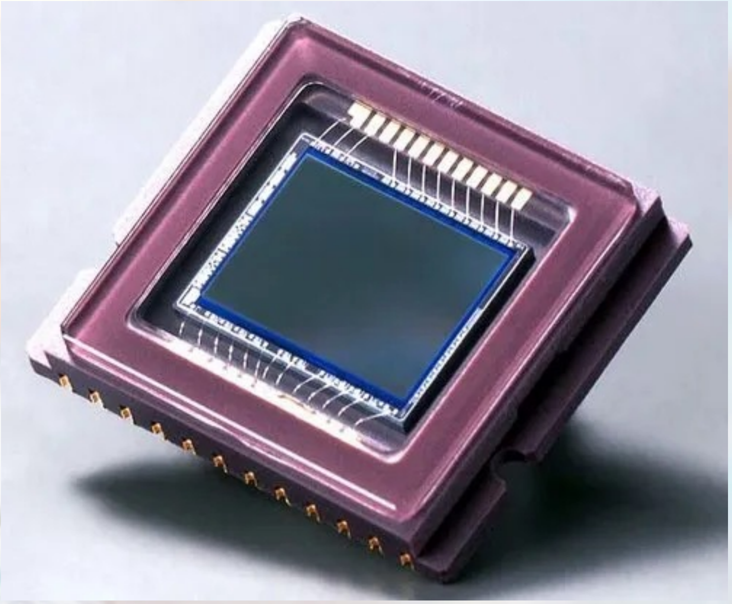
To maximize the ratio of the beacon signal to the background, including the sun and sun reflections, we used a few strategies:



- Thermally-stabilized 880nm laser diode beacons.
- A wide-angle lens that was fully telecentric in the rear at f11 (designed and made by Martin High of Applied Physics Specialties Inc.)
- A narrow bandpass filter integrated with the sensor cover glass.
- A temperature-stabilized camera (including the cover glass).

Landing helicopters on ship deck

I was using a CID imager, because CMOS imagers were not invented yet, and because CID imagers saturated to black and had no blooming. This was important with the sun in the image.



We were using zero-defect imagers as landing helicopter is mission critical.

The bandpass filter was being deposited onto the sensor cover glass.

This meant that the coating also had to be zero-defect (under a 10x loupe, 20-20 vision) due to its proximity to the 6um pixels.

Landing helicopters on ship deck

I approached all of the big coating companies (OCLI etc.) and a lot of the small ones. I got only one response, from Geza Keller, then at Cascade Optical Coatings.

First run, Geza and his shop cut and polished a batch of windows. We inspected them all, and then he applied a 7-layer AR to the first side. We then inspected all of the substrates again and applied the 63-layer bandpass filter to the second side, with a very high yield. Geza had a lot of zero-defect bare substrates left, so he put them in a cleanroom glove-box on hi-dri N_2.

Landing helicopters on ship deck

I hand-carried all of the zero-defect windows to Cidtec for attachment to zero-defect sensors.

Three weeks later I returned to CoC in Anaheim from Toronto to have Geza run a second batch of sensor cover glasses.

We reinspected the substrates, laid down the 7-layer AR and the 63-layer bandpass. Defects everywhere. After much experimentation with cleaning substrates, we came to the conclusion that: ONLY FRESHLY POLISHED SUBSTRATES CAN YIELD DEFECT-FREE COATINGS.