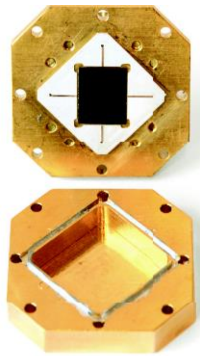
Josephson Parametric Converter QCI-JPC0509-F and QCI JPC0575-F User Guide



Device Description:

The device consists of two modes (signal, idler) which are addressed by two ports (S,I). Each of these can be coupled via microwave hybrids (included but not shown in diagram) to form a phase-preserving amplifier powered by a microwave pump (via pump port) at the sum of two mode frequencies. The mode frequencies are tuned via an external flux bias coil (provided).

Mounting Requirements:

For stable operation the device requires a stable mount and magnetic field. QCI Inc. provides a multi-layer Amuneal and aluminum shield, with a copper thermalization bracket, which should be rigidly mounted to the base stage of a dilution refrigerator.

For best performance, all microwave inputs and outputs should be appropriately filtered. A low noise following amplification chain is also a pre-requisite for quantum limited amplification (see page 5).

System configuration:

The signal to be amplified should be connected to the appropriate frequency port (here S) via a circulator as shown. All unused ports (here I) should be terminated with cold 50 Ω loads.

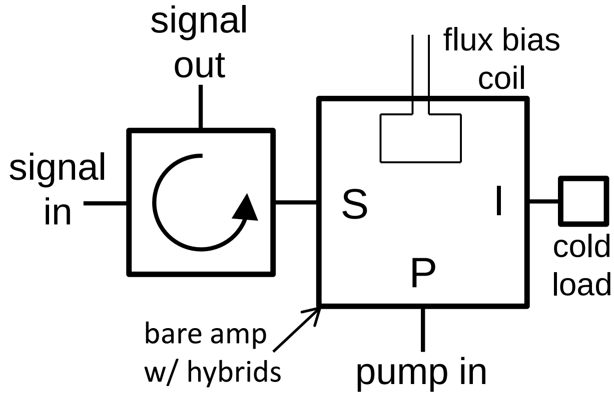


Table of Contents

This document is designed to help you setup and use your new amplifier. It is broken up into the following sections:

Warranty Information

1. Quantum Circuits, Inc. (QCI or Seller) warrants to the original purchaser each product it manufactures to be free from defects in material and workmanship for a period of one year from date of shipment, as indicated in the QCI's packing list.

2. Warranty returns must first be authorized by QCI. The Buyer will pay for the cost of inspecting and testing products returned under warranty which are found to comply within an acceptable range from the original factory test data for the particular product or which are not defective or not covered by this warranty.

3. Warranty repairs are warranted for a period of 90 days. For products still under original warranty, the original warranty will take precedence, if longer.

4. The Buyer must make a warranty claim in writing to QCI before expiration of the original warranty period or repair warranty period, as applicable.

5. Limitations on liability:

    a. This warranty shall not apply to any product that has been disassembled, modified, physically or electrically damaged, or operated outside the absolute maximum ratings stated in its datasheet. Products damaged by electrostatic discharge or act of God are not covered under this warranty.
    b. QCI's liability under this warranty is limited, at the QCI's option, to the repair or replacement of the product, if found defective in material or workmanship.
    c. QCI's aggregate liability in damages shall never exceed the net selling price for the product.
    d. This warranty is invalid if the factory-applied serial number has been altered or removed from the product.
    e. QCI shall not be liable for any incidental, consequential, indirect, special, punitive or exemplary loss or damage incurred through the purchase or use of any of QCI's products. This limitation applies whether a claim is based on contract, tort or another legal theory and whether or not QCI is advised of the possibility of such loss or damage.

6. This warranty does not cover Buyer instruction, installation and set up actions or problems.

7. QCI reserves the right to make design, or other changes, to any of its products without incurring any obligations to make the same changes to previously sold units.

8. QCI makes no other warranty of any kind, whether express or implied, for its products. QCI disclaims the implied warranties of merchantability and fitness for a particular purpose.

Warnings and Cautions

The Amuneal can and lid (the larger, shiny, silver colored can and matching lid which together form the outer shielding for the amplifier) have been hydrogen annealed in order to maximize their magnetic shielding abilities. Drops or other impacts can degrade performance and the shield will need to be re-annealed. Impacts which degrade the shielding may not leave any visible damage. Please treat the can and lid as if it were made of glass. Re-annealing due to mishandling is not covered by our warranty.

The magnet is made out of copper clad Nb/Ti superconducting wire. The resistance of the magnet (nominally few hundred ohm at room temperature) will change as the magnet cools and excessive amounts of current may cause the magnet to quench.

The solder joint connecting the magnet lead to the connector is delicate. Care should be taken in handling the connector, and the magnet should never be supported by the connector.

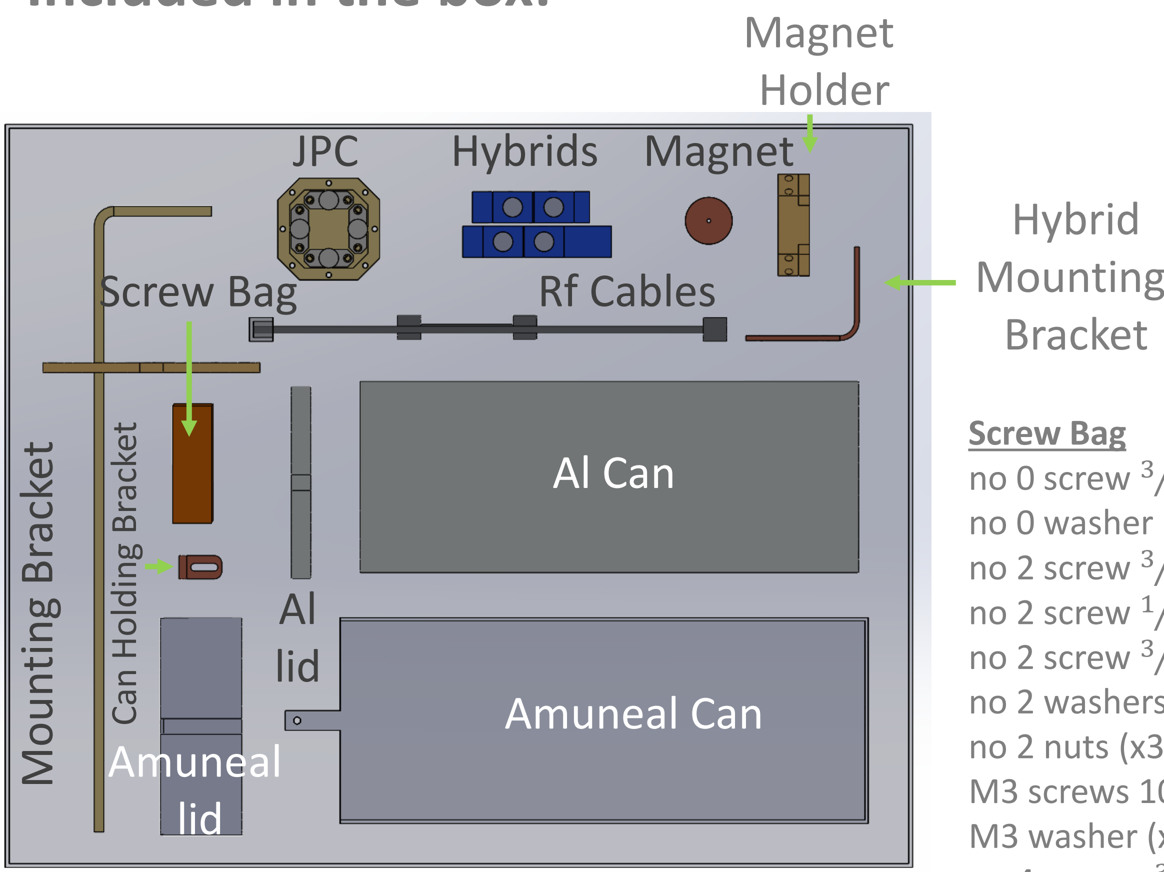
The JPC amplifier chip is shipped in a closed, connectorized package. The amplifier chip is extremely delicate and the package should not be opened without the explicit direction of QCI support staff.

Included in this manual are a few examples of how the JPC can be integrated into an experimental setup, but many other options exist as well. If you need help integrating the JPC into your specific experiment QCI is happy to help. Please contact support at support@quantumcircuits.com.

Additional information about proper use can be found in the 'tuning procedure' and 'troubleshooting and FAQ' sections of this guide.

Bill of Materials

Included in the box:



Screw Bag

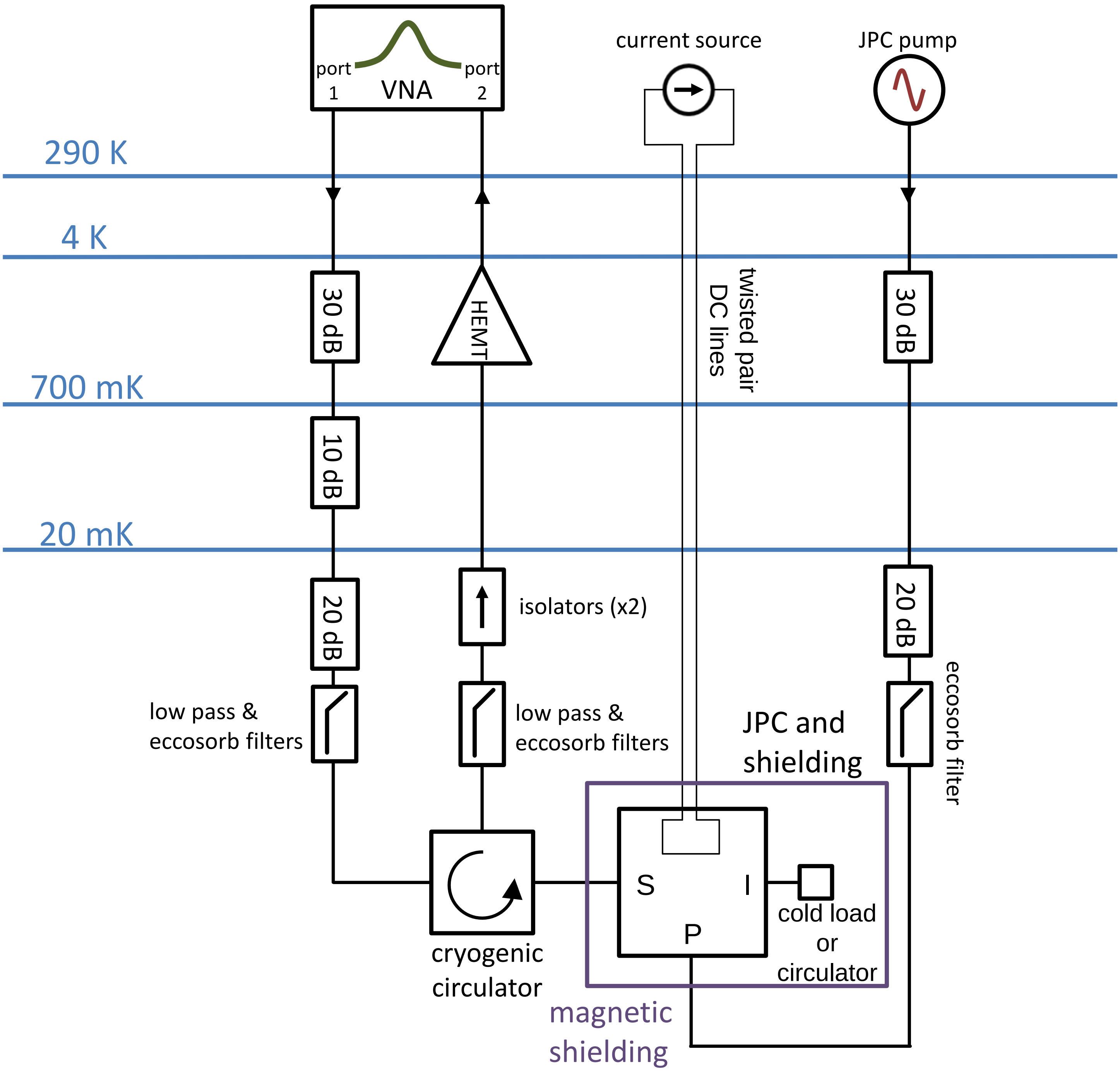
no 0 screw $^{3}/_{8}$ inch (x2)
no 0 washer (x2)
no 2 screw $^{3}/_{8}$ inch (x3)
no 2 screw $^{1}/_{2}$ inch (x3)
no 2 screw $^{3}/_{4}$ inch (x6)
no 2 washers (x15)
no 2 nuts (x3)
M3 screws 10mm (x3)
M3 washer (x3)
no 4 screws $^{3}/_{8}$ inch (x6)
Low profile no 4 screws (x6)
no 4 washers (x18)
no 4 nuts (x6)

Also required (but not included):

- Dilution refrigerator equipped with the following:
    - 1-3x rf input lines (number depends on application)
    - 1x rf output line. Superconducting output lines recommended for optimal performance
    - 1x twisted par of dc-wire for magnet
- HEMT amplifier at 4K stage (Low Noise Factory or similar recommended)
- Cryogenic isolator (2x) at base between JPC and HEMT
- Cryogenic circulator (1-2x) at base between JPC and sample (necessary for most applications)
- Pump generator (amplitude stability is crucial. Agilent MXG or similar recommended)
- Stable current source for magnet (Yokogawa GS200 or similar recommended)
- Network Analyzer required for initial tuning and recommended for troubleshooting. See ‘tuning procedure’ for details.

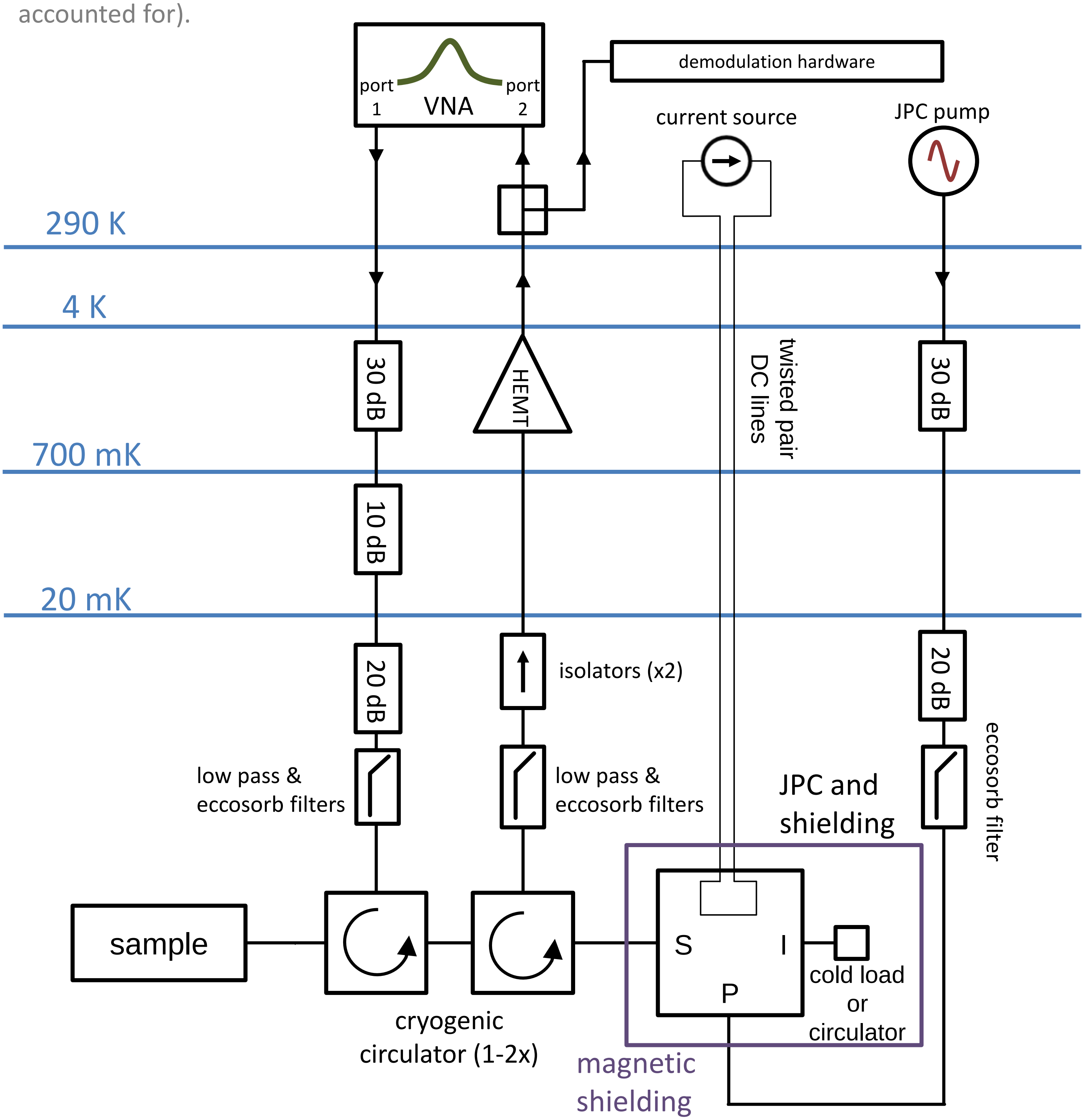
Example Setup: JPC Alone

This is the suggested experimental setup for measuring the JPC alone. It is useful to either gain experience with the operation of a JPC, or to diagnose problems. It easily allows for the recreation of the curves shown in this guide. To directly access the idler port, a circulator can be attached at the point indicated and the input and output line configuration shown for the S port can be mirrored.



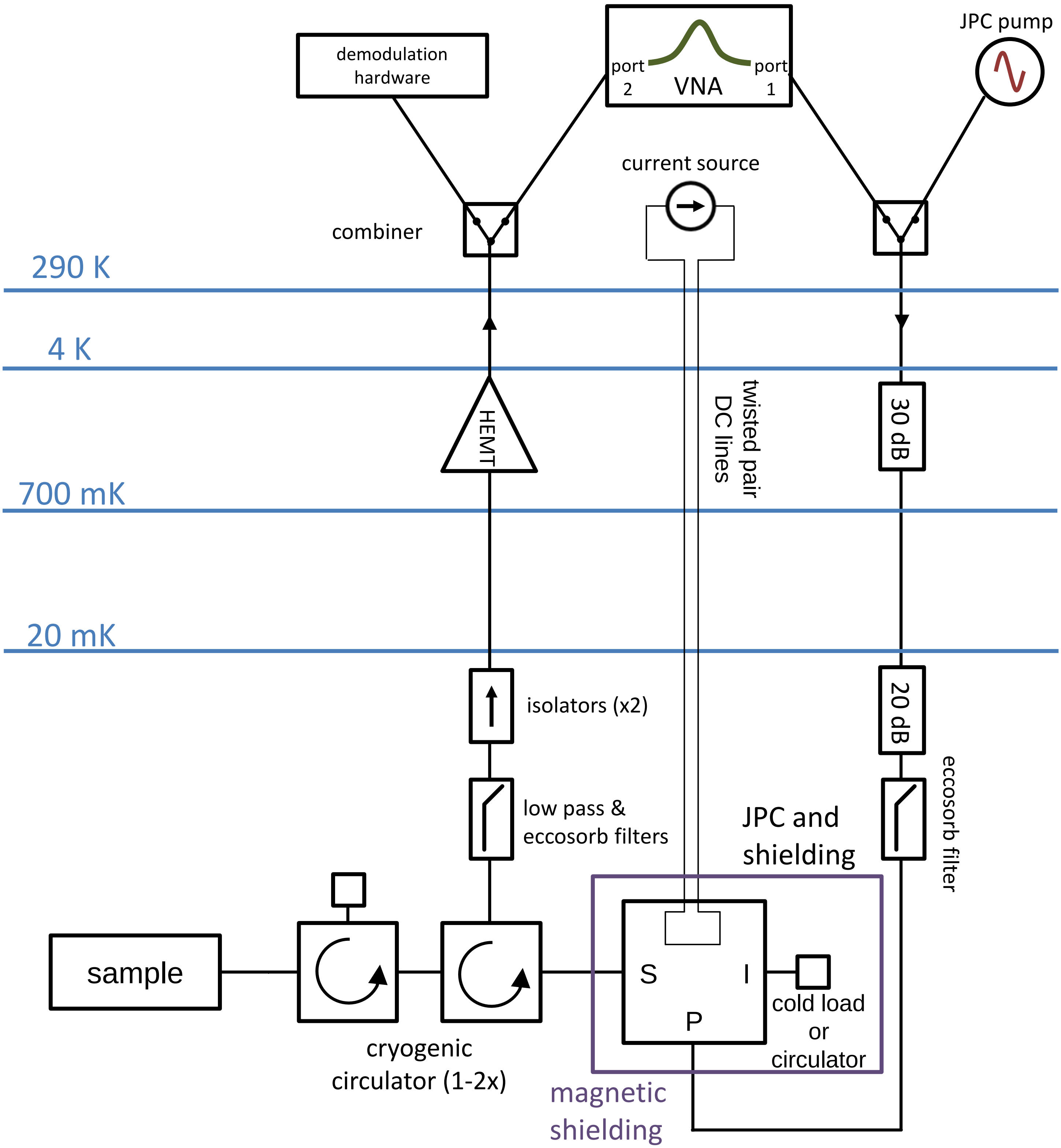
Example Setup: Standard Configuration

This is the suggested experimental setup for the majority of users. It allows direct access to the JPC for ease of tuning, monitoring, and troubleshooting, while still allowing the JPC to amplify a sample of interest. Please note the JPC amplifies in reflection, and the isolation between the JPC and your sample for a given amount of gain depends critically on the number of circulators and the amount of transmission loss separating them. To also use the I port, the setup attached to the S port of the JPC can be mirrored. Please note the JPC adds its inputs, so the two ports should not be driven simultaneously (unless this effect is accounted for).



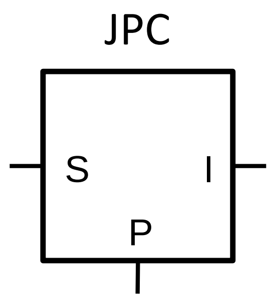
Example Setup: Advanced Configuration

This example setup minimizes the number of dilution refrigerator lines and equipment that is needed, but at the expense of more difficult JPC tuning and monitoring. Recommended for experienced users only. Please see 'tuning procedure' for more information.

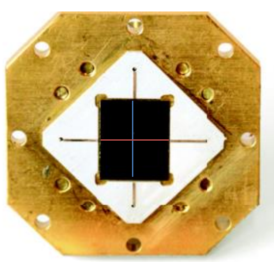


Setup Notes: Expanding the JPC Block

In the example experimental setups on the previous pages, the JPC was represented by this block diagram:



The JPC box has four SMA connectors, two of which are connected each end of a λ/2 resonator (red), and the other two of which are connected to the ends of a second λ/2 resonator (blue). On the box, there is an engraved 'S' indicating one of the SMA connectors attached to the signal (red) resonator.

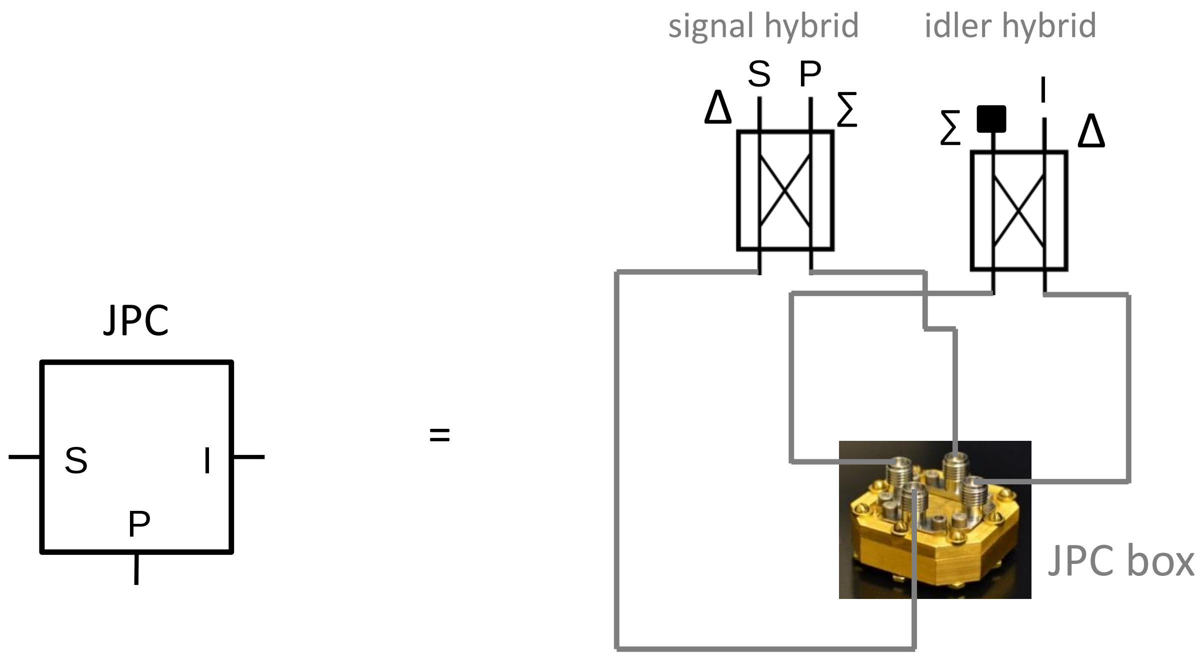


Inside

Outside

The signal mode of the device corresponds to a differential excitation of the red resonator, and the idler mode corresponds to a differential excitation of the blue resonator. To get the proper excitation, a 180° hybrid must be connected the two SMA connectors which address the desired mode (see next page). The Δ port of that hybrid then becomes the signal (or idler) port (S or I) as labeled in the black diagram, and the Σ port becomes the pump port (P). If both modes will be used, a 180° hybrid should be connected to each of them and then the Δ port of the hybrid connected to the red resonator will correspond to the signal port (S), the Δ of the hybrid attached to the blue resonator corresponds to the idler port (I), and the Σ of the hybrid connected to the red resonator corresponds to the pump port (P). Once the amplifier is assembled and all of the shielding cans have been closed the JPC will again resemble the block diagram:

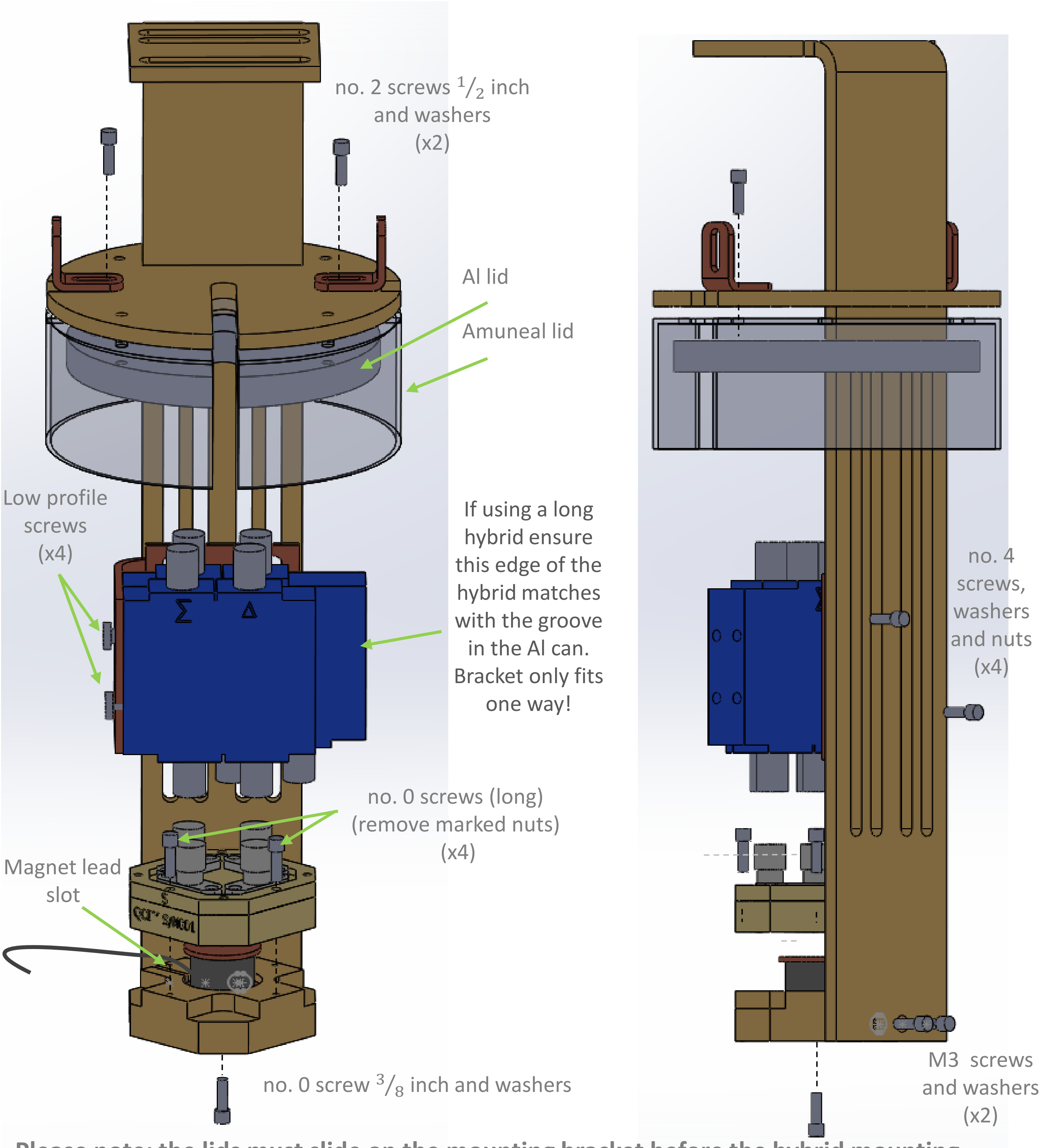
Setup Notes: Expanding the JPC Block



See the ‘amplifier assembly’ section for even more information.

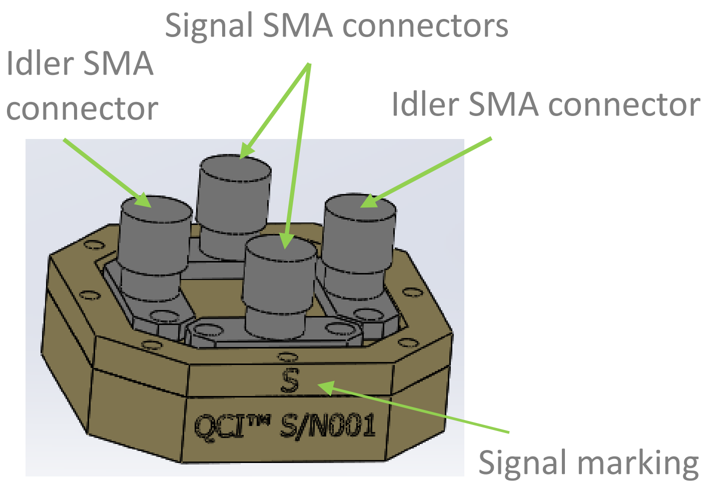
Amplifier Assembly

1. Assemble components

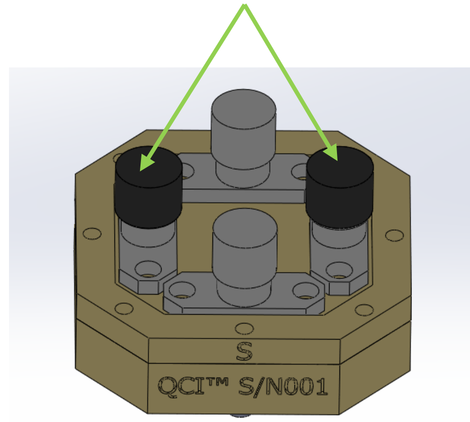


Please note: the lids must slide on the mounting bracket before the hybrid mounting bracket and magnet holder are attached and that the Al lid is not symmetric. The side with extra holes must face up. If only one port (S or I) is to be used, only one hybrid needs to be mounted. Both are shown above for completeness.

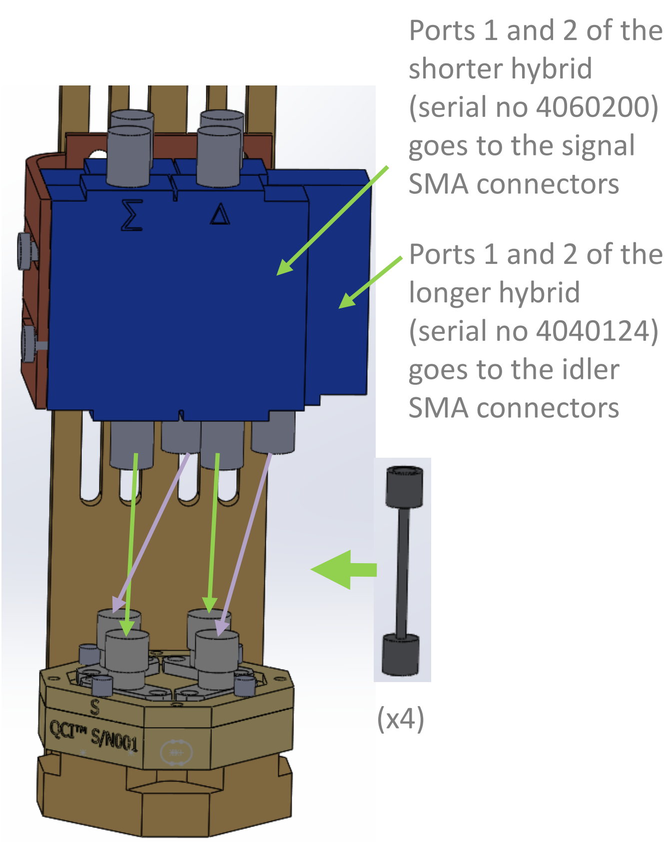
2. Identify ports of the JPC box



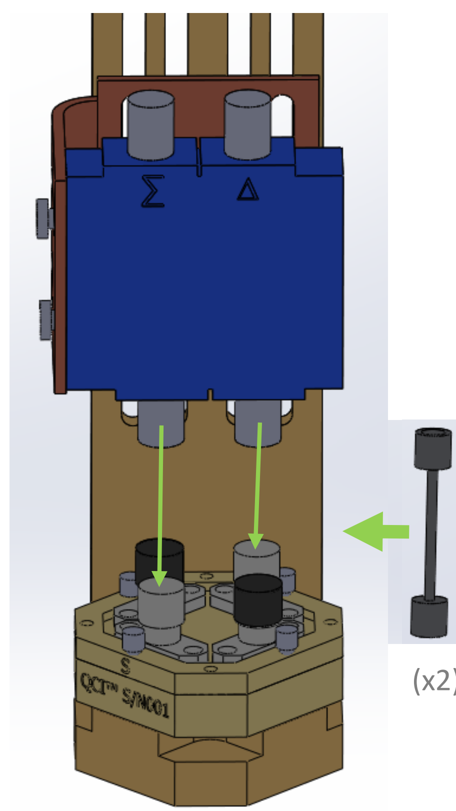
If only one resonator will be used (here S), terminate the other two SMA connectors in cryogenic 50 Ω loads



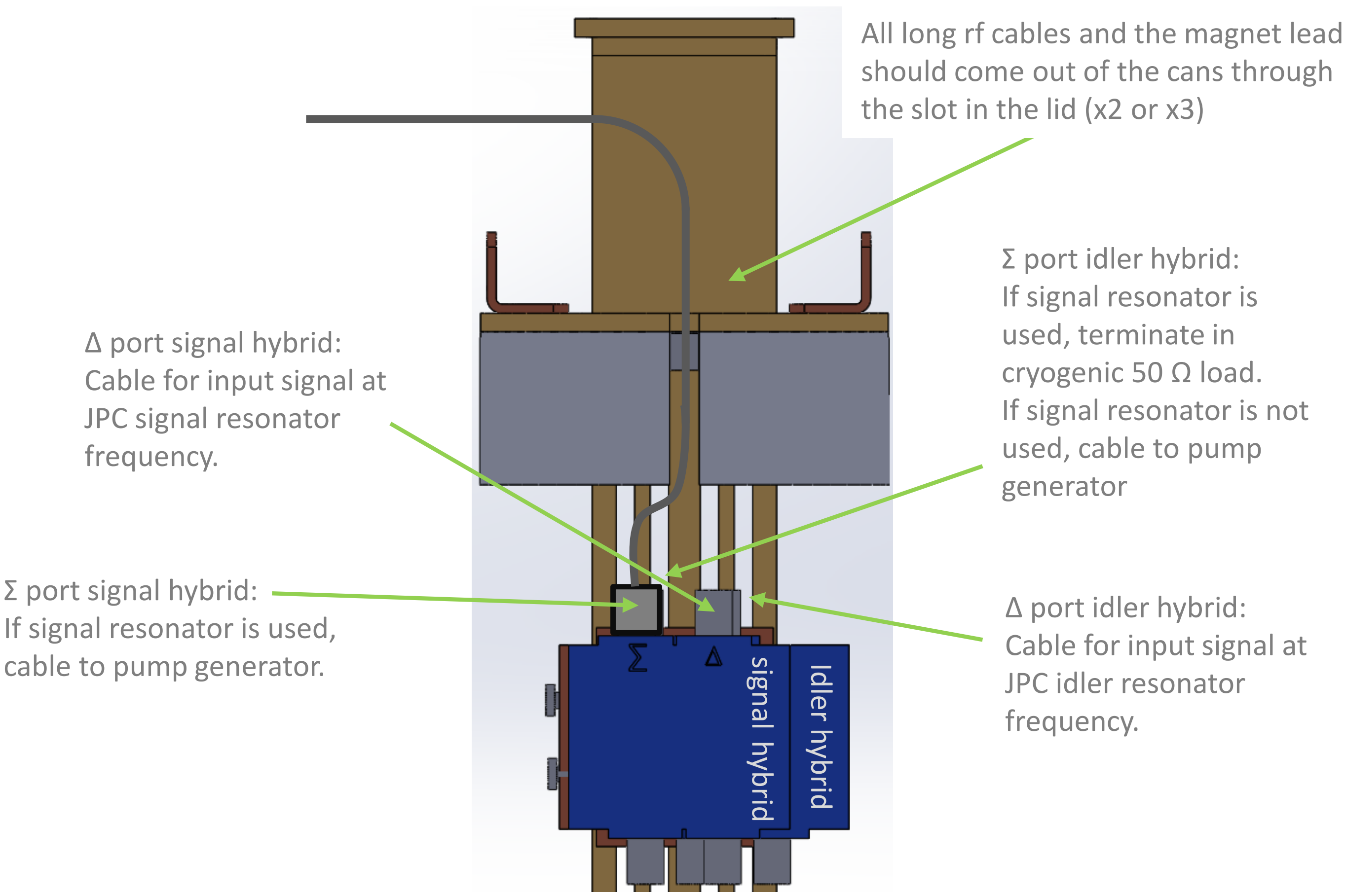
3a. If using both resonators attach short cables as shown:



3b. If using one resonator attach short cables as shown:

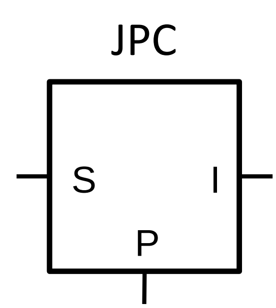


4. Attach long rf cables to Σ and Δ ports of the hybrids



Compare to the physical structure above to the block diagram of the JPC shown in the example experimental setups (and reproduced at right):

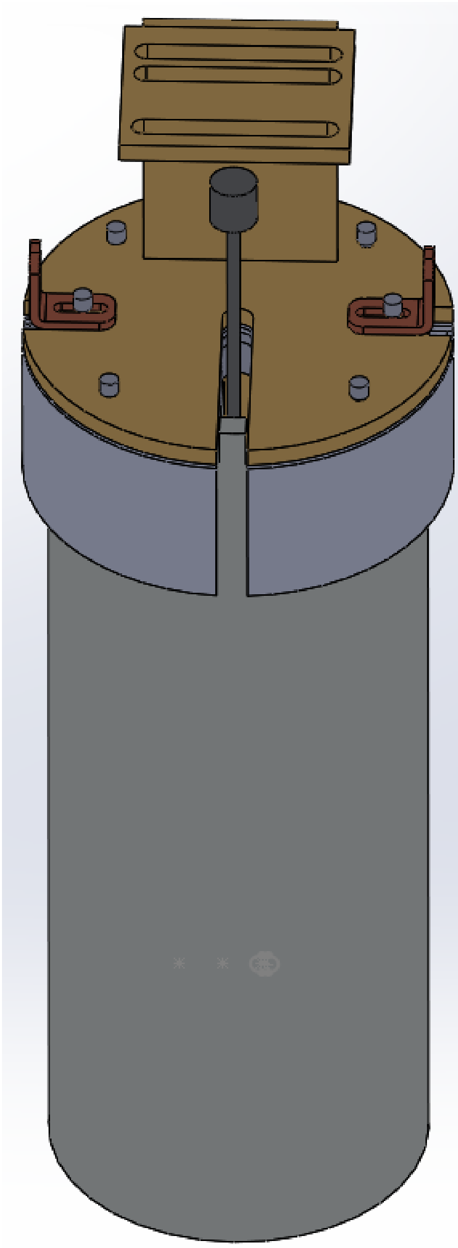
- The Δ port of the signal hybrid corresponds to the S port at right
- The Σ port of the signal hybrid (or idler hybrid, depending on setup) corresponds to the P port at right
- The Δ port of the idler hybrid corresponds to the I port at right



Amplifier Assembly

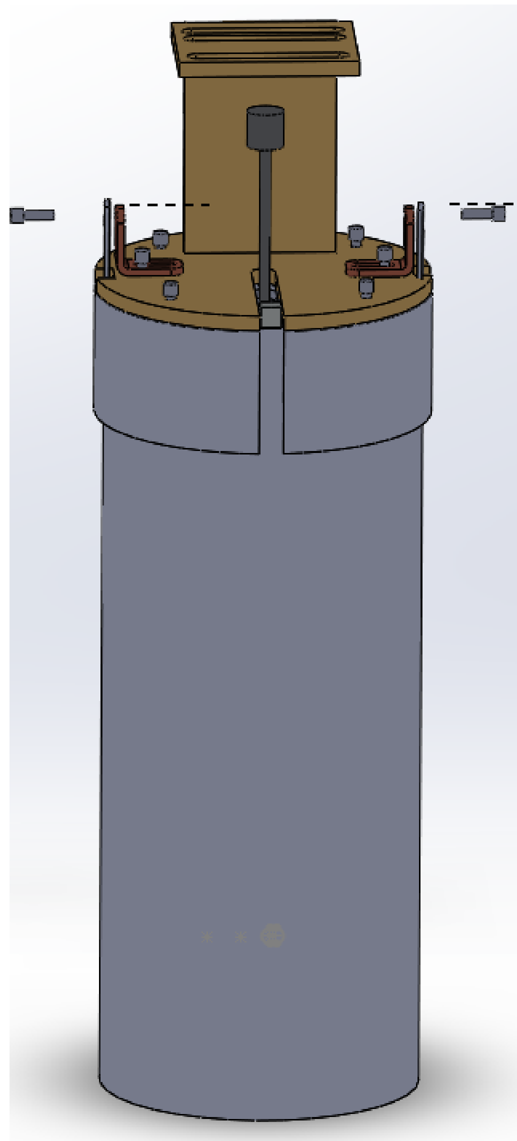
5. Close Al can. Secure with screws through lid. The Al can is keyed to help with screw alignment.

no. 2 screws $^{3}/_{4}$ inch and washers



6. Close Amuneal can. Secure with side screws, washers, and nuts.

no. 2 screws $^{3}/_{8}$ inch

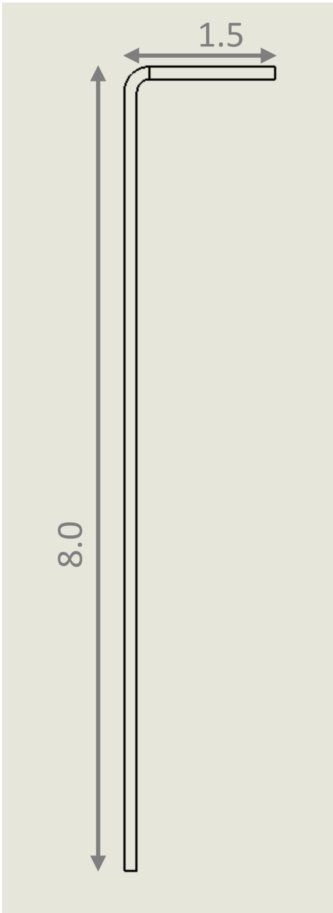


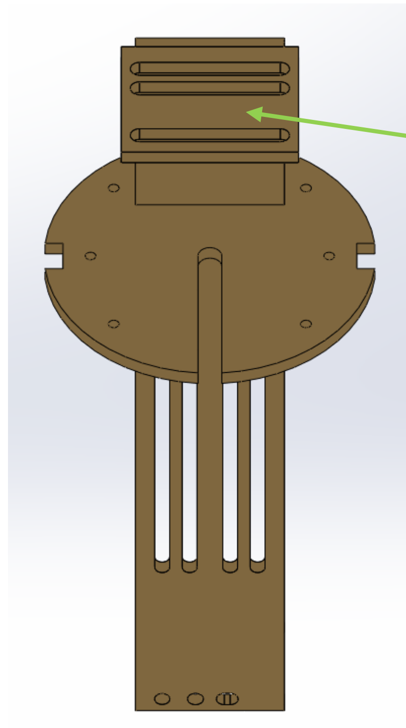
Please note: if both hybrids are being used, the fit for the inner Al can is very tight. Shifting the position of the hybrids on the bracket may be necessary to allow the can to close and tighten.

7. Mount top of the bracket to the base plate of your refrigerator. See next page for technical drawings and hole spacing.

Amplifier Assembly: Technical Drawings for Fridge Mounting

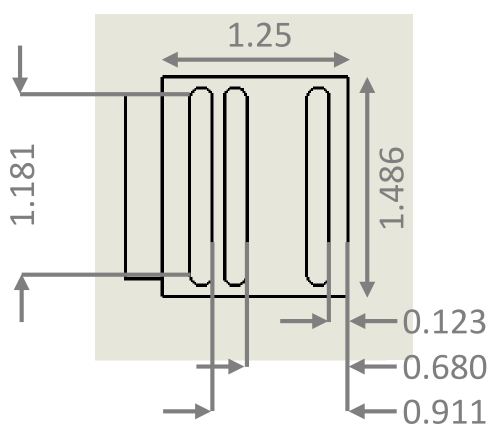
Side view





Mount to base plate of refrigerator

Top view



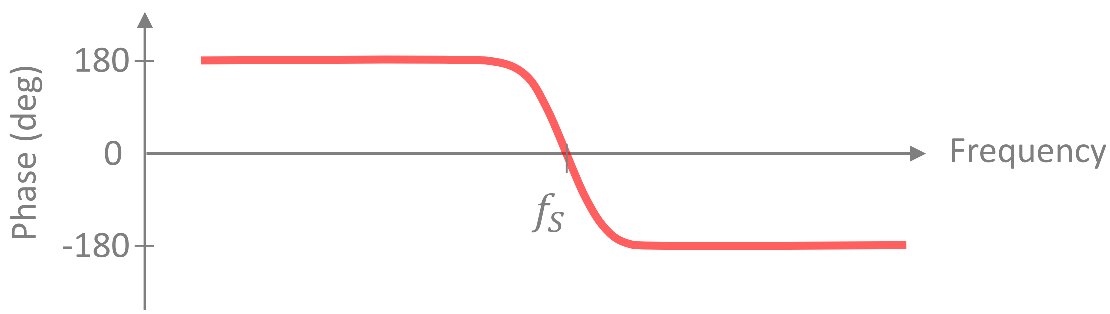
Slot width is 0.154 and designed to fit M3 screws

Please note all dimensions are in inches

Tuning Procedure

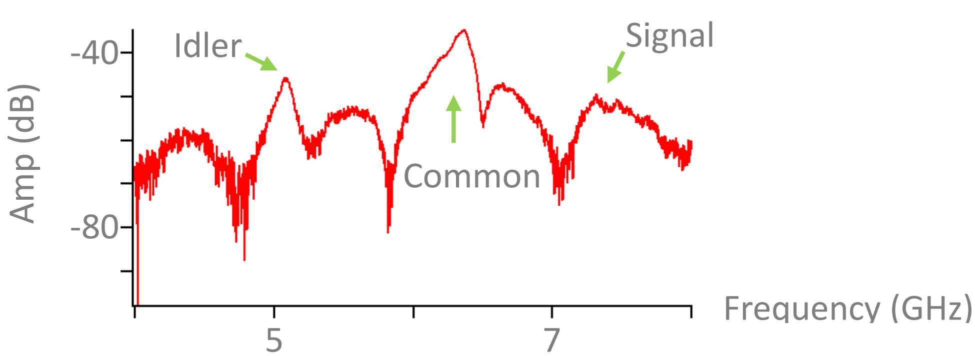
1. Identify the resonant modes of the device. This can be done by measuring the reflected phase response of either resonator (1a), or by the amplitude response as measured in the pump port and out either the signal or the idler port (1b).

1a. To measure the phase response off either resonator set the VNA to measure the phase, set the power to around -50 dBm, set the central frequency to somewhere between the quoted max and min gain frequency for that mode, and the frequency span to 3 GHz. Use the electrical delay function on the VNA to flatten out the phase response from the input and output lines, and the phase offset function to reproduce a curve similar to this:



The linear bandwidth of both the signal and idler mode is around 100 MHz. Neither the signal nor the idler mode will show significant response in amplitude.

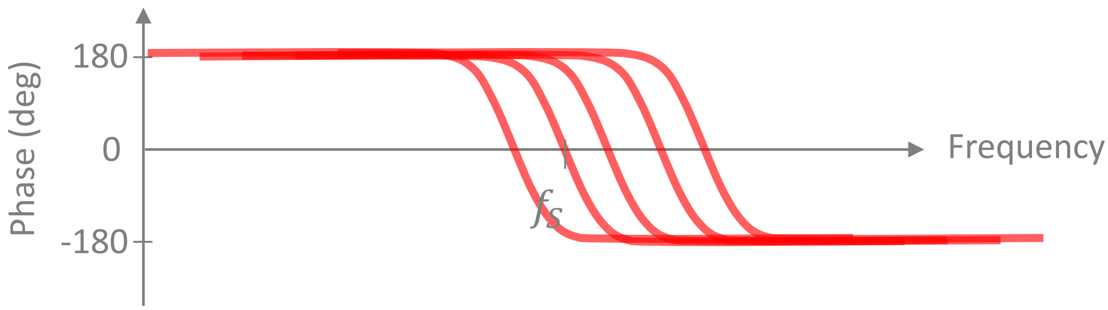
1b. Measure the amplitude response of the JPC looking in the pump port and out either the signal port or the idler port. On a VNA this can be done by setting it to measure amplitude, setting the power to around -50 dBm, the minimum frequency to 1 GHz below the expected idler frequency and the maximum frequency to 1 GHz above the expected signal frequency. The response will look similar to this:



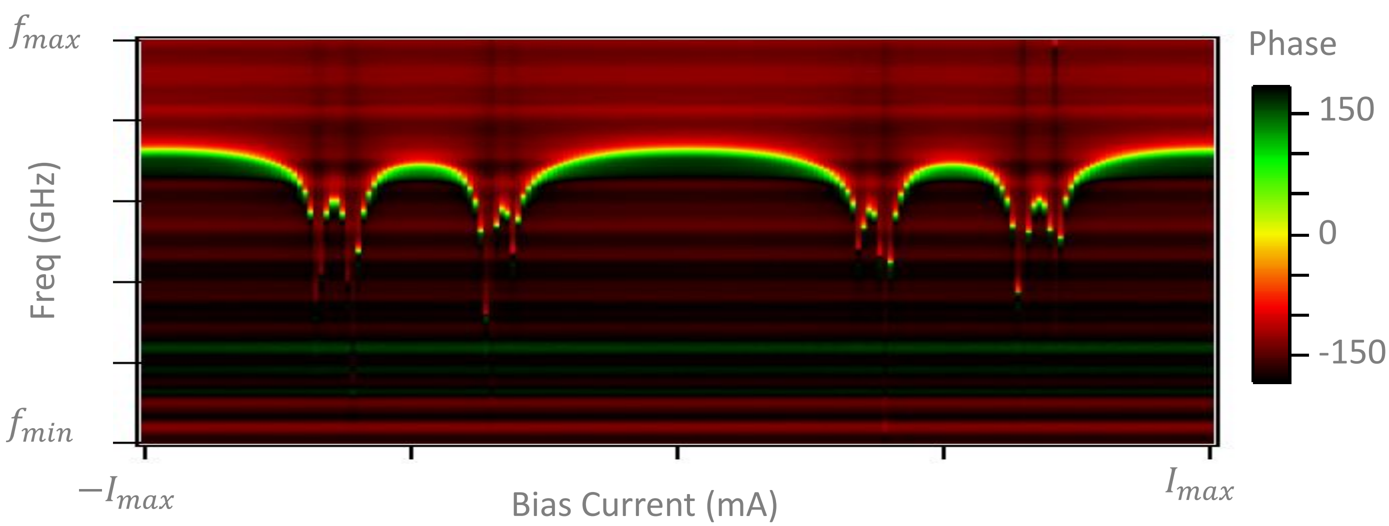
The signal and idler modes may both be visible, as well a third mode of the JPC (the common mode) whose frequency is in between the two, typically somewhat closer to the signal.

2. To more easily differentiate the three modes from the background transmission, change the bias current through the magnet and see which resonances move in frequency. The response of lines can also be subtracted by using the data/mem feature on the VNA. Please avoid taking large steps in current bias (> 0.1 mA) to avoid trapping flux in the device.

3. Next one needs to identify the range of bias currents over which the JPC will amplify. As the bias current through the magnet is changed, the linear resonance of the device change in frequency. The resonant frequency will increase until it hits some maximum value, and then will begin to decrease. If you keep increasing the flux it will hit some minima, and then will begin to increase again.



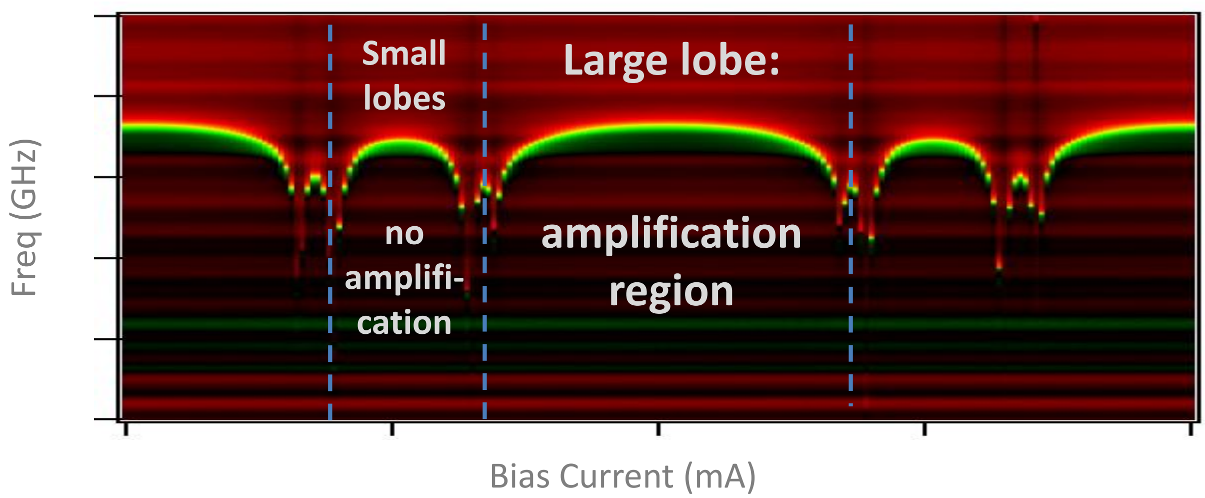
3. As the bias current is swept, the maximum linear resonance will over some bias current ranges. The full frequency response of the resonance as a function of bias current looks like this:



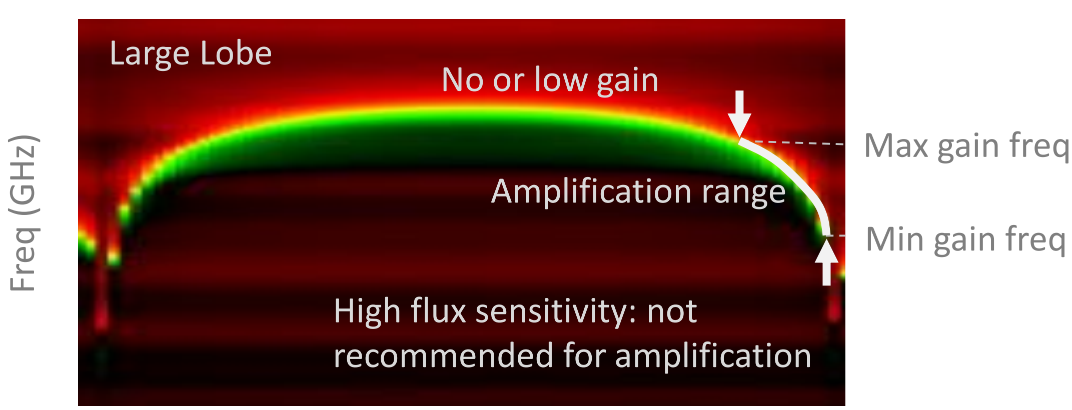
The linear resonant frequency of the mode is traced out in yellow, and a vertical cut at any specific bias current will result in a phase response similar to that pictured in step 1a. This graph, where the linear resonant frequency appears as a function of bias current, is known as a flux sweep. We call it a flux sweep because the change in current corresponds to a change in flux through a ring of Josephson junctions which forms the heart of the JPC.

Tuning Procedure

4. The JPC only behaves as an amplifier when biased on a ‘large’ lobe of the flux sweep.
  - Large lobes have a higher maximum linear resonant frequency. Before biasing, the JPC should be swept through a few different lobes to ensure a large lobe has been found.
  - The resonant frequency of either mode of the JPC depends on the absolute magnetic field it is exposed to. Thus there may be a difference in the measured resonance frequency and what is reported on the included flux sweeps for any particular bias current. Always use the measured value of the resonant frequency of the JPC instead of relying exclusively on the provided flux sweeps.
  - Note that a third (common) mode exists between single and idler, and may also be visible when looking at the signal and idler modes. Do not use this mode for amplification.
  - Best performance will be found on the large lobes closest to zero applied bias current, but all large lobes can be used for amplification.
  - For details on how to measure a flux sweep see the troubleshooting and FAQ section.



5. Once a large lobe has been found, tune resonator so the resonant frequency of the mode matches the desired amplification frequency. Please note the frequency range over which the JPC amplifies is smaller than the range the linear frequency tunes.

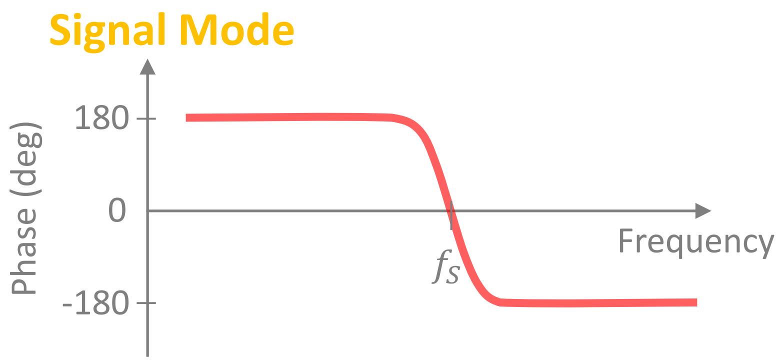


The large lobes are symmetric, and either the left or the right side can be used for amplification. Only the left side is highlighted above for simplicity.

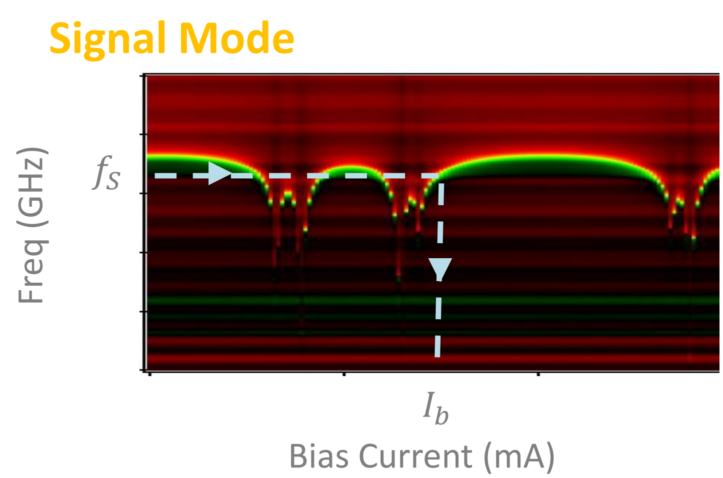
6. Next, the frequency of the other mode must be determined. This can be done one of three ways:
6a. If both resonators can be directly accessed, measure the phase response directly by looking at the reflected phase response of the other mode.

OR

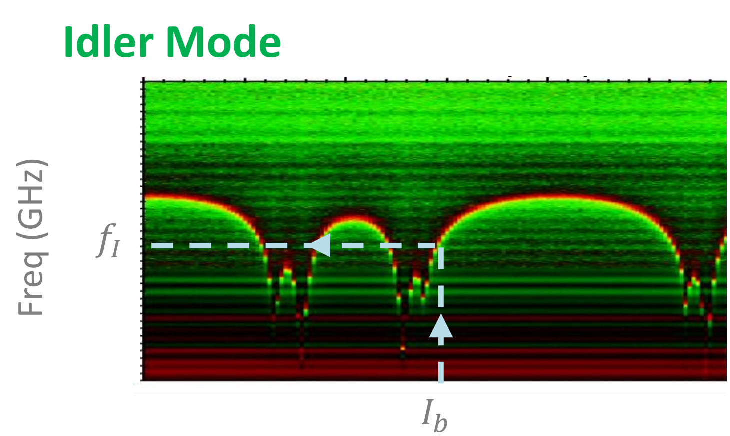
6b. If the other resonator is terminated, use the provided flux maps:



Measure the frequency of the visible resonator



Use this frequency (f_S) to find the corresponding test bias current (I_b) as measured at QCI. Note that there may be offsets between the actual applied current and I_b found on the flux sweep due to differences in the magnet, or in the background magnetic field. Make sure the amplifier is biased on a major lobe!

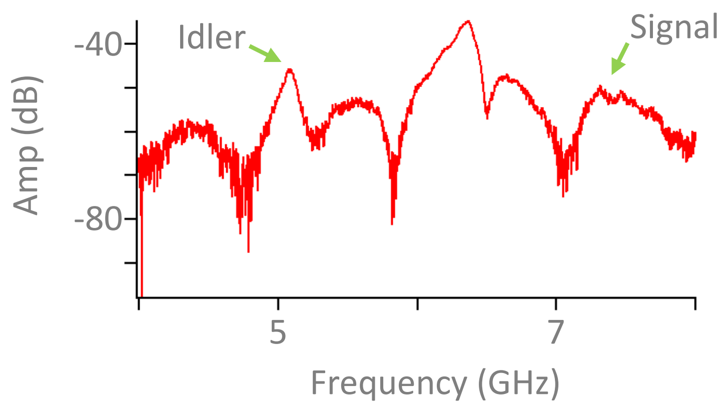


Find I_b on the flux map for the other resonator and look for the frequency at which the phase response is zero. This is the frequency of the other resonator here labeled f_I.

Tuning Procedure

OR

6c. Look at the amplitude response of the devices as measured looking in the pump port and out either the signal port or the idler port. The signal and idler mode should both be visible, as well as a third mode known as the common mode. The response will look something like this:

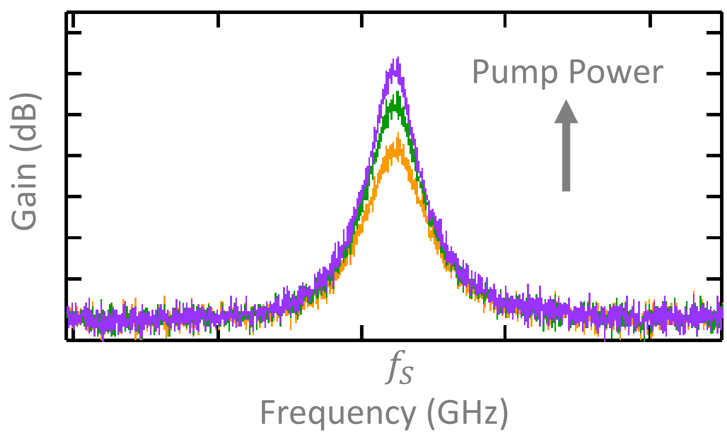


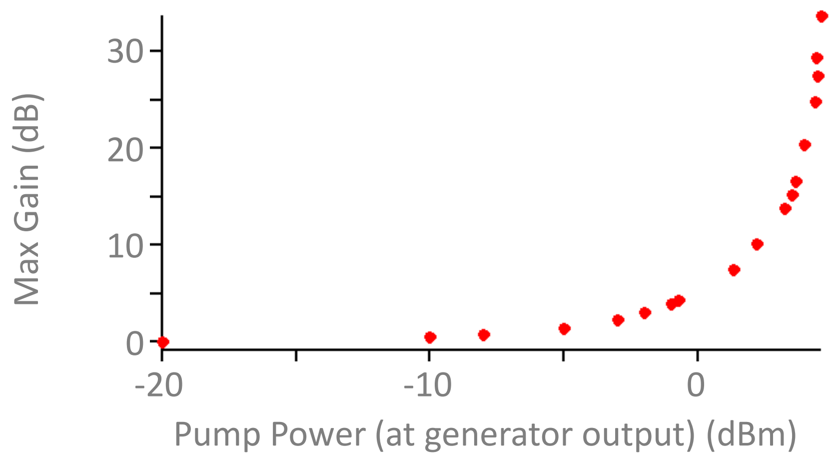
The modes may be harder to differentiate from other features in your experimental setup. Changing the magnetic bias and observing which features move in frequency may help differentiate the modes of the JPC from other features in the lines.

7. The pump frequency should be set to the sum of resonant frequency of the signal mode and the idler mode. For example, if $f_s = 7.5$ GHz and $f_I = 5$ GHz then $f_{pump} = 12.5$ GHz.

8. Switch to looking at the reflected amplitude response of the desired mode on the VNA. Narrow the frequency span on the VNA to around 100 MHz centered around the linear resonance of the JPC. Normalize out the background (pump off) response by saving an averaged amplitude trace to the memory of the VNA, and then using the data/memory feature. Before turning the JPC pump power on, set the VNA power to around -60 dBm. Set the pump power to -20 dBm, turn on automatic leveling control (ALC), and turn the pump power on.

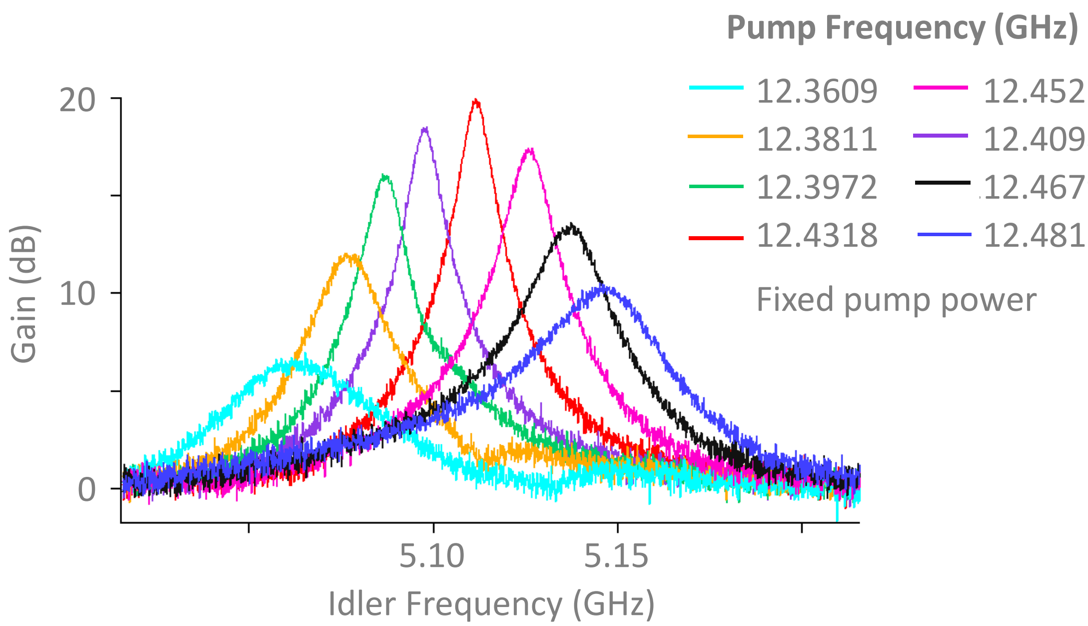
9. <u>Slowly</u> begin to increase the power of the pump generator until you a Lorentzain gain curve begins to appear. The peak of the gain curve will be near the resonant frequency of the mode. Gain is a nonlinear, and rapidly accelerating, function of pump power, so once the gain becomes visible, use 0.01 dBm steps on the pump generator. Below is an example set of gain curves taken at a few different pump powers, and a graph of JPC gain as a function of pump power.





- If the pump power is too strong, amplifier gain will begin to drop again. Do not use in this regime as the amplifier will be unstable and noisy.
- The gain curve should be symmetric, and the 3 dB bandwidth at 20 dB of gain will be close to the quoted value found in the device specific test data section of this manual. If this is not the case, check you are using the correct pump frequency and attempt to re-bias.
- The gain may also be limited by the probe power of the VNA. Turn the VNA power down by 5 dBm. If the amplifier gain increases, decrease the VNA power further until the value of the amplifier gain does not change anymore. VNA power is typically around -60 dBm for input lines with around -75 dBm of fixed attenuation.

10. Small changes in the frequency of the gain can be achieved by changing the pump frequency, and then re-sweeping the pump power from low to high. Please note the frequency of the gain will move by half of the amount that the pump frequency was moved, and at offset pump frequencies the maximum achievable gain will be lower (as shown below). Change the pump frequency in 5 MHz steps or smaller.



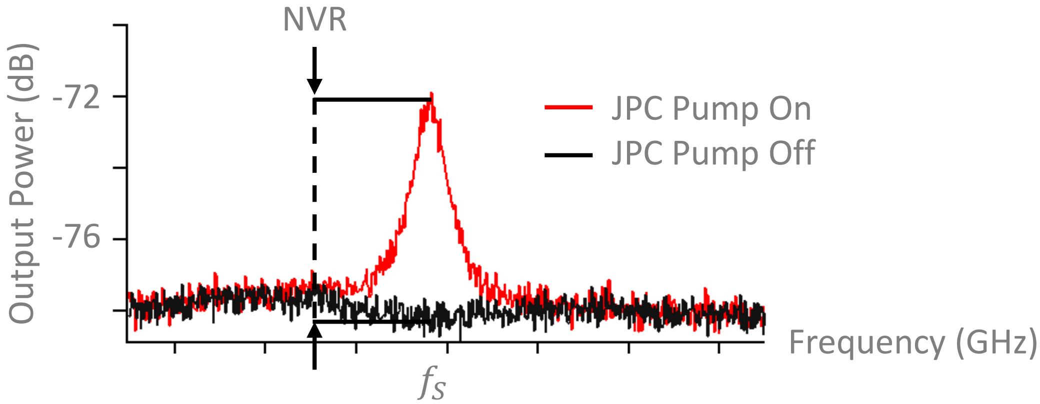
11. To achieved larger gains at one of these offset pump frequencies, first increase the pump power. If that does not result in enough gain (or if the gain curve begins to look asymmetric) move the linear resonance of the JPC by changing the bias current through the magnet, and then re-sweeping the pump power from low to high. The highest gains will be achieved when the linear resonance of the JPC and the center of the gain curve are nearly commensurate. By alternating between changing the pump frequency, magnet bias, and pump power the gain can easily be moved over a large frequency range.

12. To move the gain by larger frequency steps turn off the JPC pump, move the linear resonance of the JPC to the new frequency and repeat steps 1-6 of this tuning procedure.

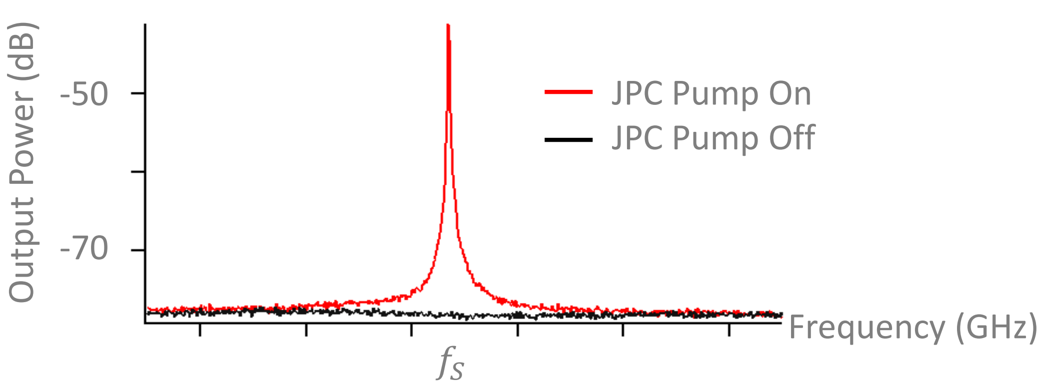
Advanced Setup Comments

If using the 'advanced' example experimental configuration (shown on page 8), directly measuring the reflection gain of the JPC in the way outlined above will not be possible. The JPC will still respond to changes in pump power, pump frequency, and magnetic coil bias in the manner described above, but ensuring the gain is correctly tuned and determining the exact value of the gain is more challenging.

- If a spectrum analyzer is available, the output spectrum of the JPC can give an indication of amplifier gain. Once the gain of the JPC is large enough for amplified quantum noise from the JPC to dominate the noise of your system, the output spectrum looks like the following:



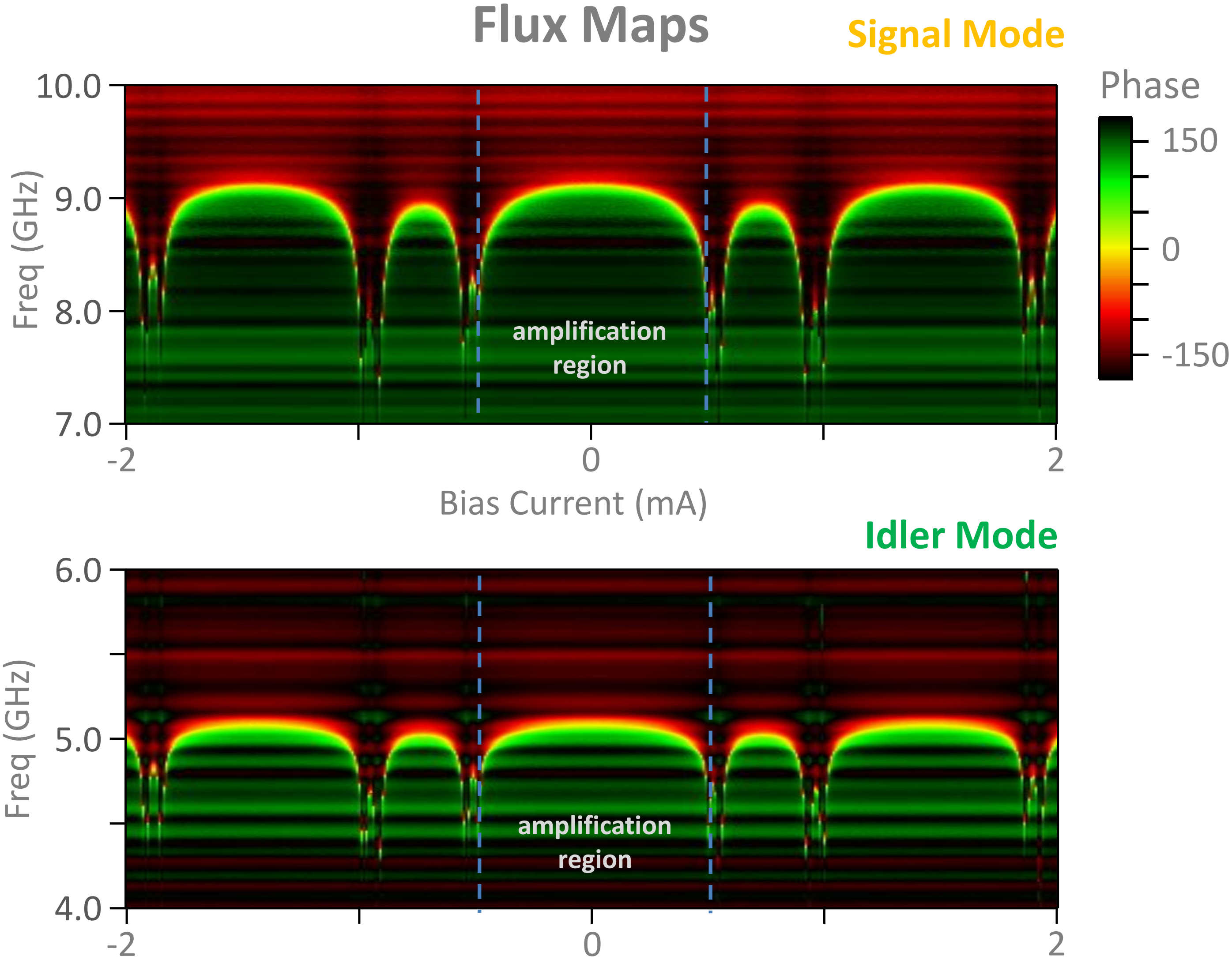
- If the amplifier is correctly biased this curve should also be smooth and symmetric. The exact value of the height of the peak will depend on the gain of the JPC, and the system noise temperature of the output line the JPC is using.
- The height of the peak above the noise floor (taken with the pump off) is known as the NVR, and is given by $NVR = \frac{G_{JPC}(T_Q+T_N^{JPC})+T_N^{SYS}}{T_N^{SYS}}$ where G_{JPC} is the power gain of the JPC, T_Q is the temperature associated with half a photon at the relevant frequency, T_N^{JPC} is the noise temperature of the JPC, and will be within a factor of two of the quantum limit at the amplification frequency, and T_N^{SYS} is the noise temperature of the system excluding the JPC. The NVR represents the advantage in signal-to-noise ratio you can expect from inserting the JPC as the first amplifier in your measurement chain. Please note your NVR may be different from the value given in the data sheet due to differences in the system noise temperatures. Our T_N^{SYS} for calibration is around 10 K.
- If a sudden sharp peak in the output appears (see example plot below), higher order non-linearities in the JPC may be being excited. This indicates the pump power is too high and must be reduced. You may also see some hysteresis, turn the pump off and re-sweep from low power to high.



- The amount of amplification can also be calibrated by comparing the output of your sample measured with and without the JPC. Please remember the JPC is a phase-preserving amplifier which will treat both quadratures of a signal equally, and that the gain quoted in this manual is a power gain. This is the hardest method to use to diagnose tuning problems, but may be sufficient if the biasing conditions are already well known. (For example if the amplifier has already been used in a particular experimental setup.)

Josephson Parametric Converter
Data Sheet: S/N 004

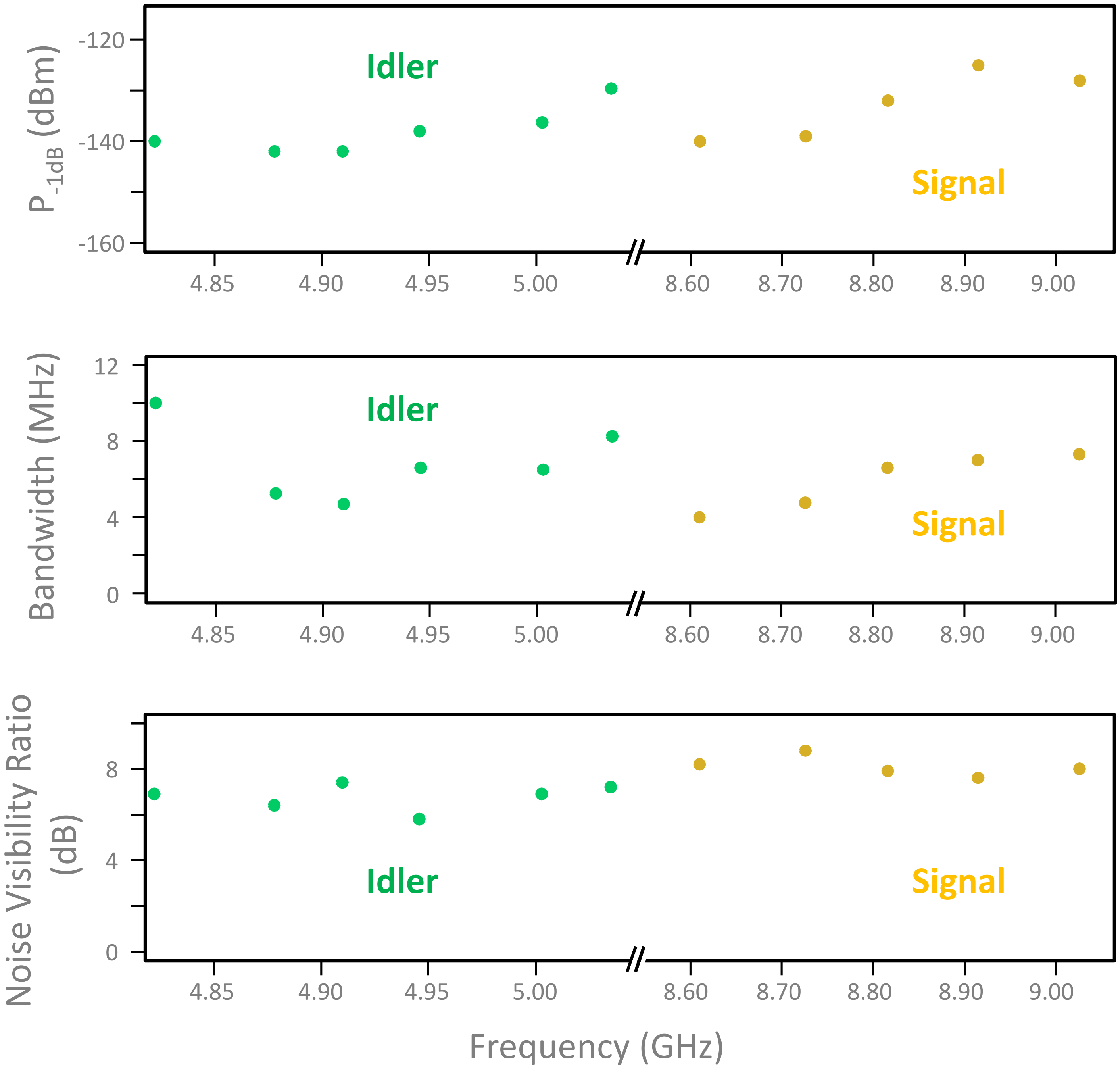
Flux Maps



(Flux map files also included in .csv format)

	f_{max} (GHz)	f_{min} (GHz)
S Mode Gain (20 dB min)	9.026	8.610
I Mode Gain (20 dB min)	5.035	4.822

Performance with G = 20 dB



Troubleshooting and FAQ

I'm having trouble connecting the 2-inch cables to the JPC from the hybrids

- If both hybrids are being used, the 2-inch cables need to include a twist

I can't see the linear resonance of the JPC

- Check that all of your system components (HEMT, room temperature amplifier, etc.) are on and working properly.
- Ensure you are looking at the phase response. The JPC should have no linear amplitude response when not pumped.
- Ensure you are looking at the correct resonator and in the correct frequency range. Upon warming up ensure you are looking at the delta port of the appropriate hybrid.
- The linear bandwidth of the JPC is on the order of 100 MHz. Ensure your VNA span is not too large and the VNA power is not too high.
- Try changing the current through the magnet and seeing if you see any change in phase. Try performing a flux sweep as described in the last section of the FAQ.
- Ensure your lines are well matched to 50 Ω. Reflections in your setup may obscure the JPC and will negatively impact performance.
- If all this fails, warm to room temperature and check your cable configuration. Pay special attention to the cutoff frequency of any filters, and the directionality of elements like circulator and directional couplers.

I can't get any gain

- Check that the pump frequency is the sum of the linear signal resonant frequency and linear idler resonant frequency.

Ensure that you are looking at the amplitude response of the JPC and not the phase response.

- Ensure you are working on a large lobe (these lobes should have the highest maximum frequency) and the frequency at which you are trying to get gain is within quoted frequency range.
- Ensure your VNA power is not too high.

- Ensure that the pump generator output power is on, automatic leveling control is on, and modulation or pulse mode (if applicable) is turned off.
- Note that too-high pump power will also result in low/no gain. Always sweep upward from low pump power.
- Look at the phase response. As the power is turned up, the phase roll should sharpen. If this does not happen, you may not be delivering enough power.
- Check that your generator can source sufficient power based on the data sheet for your JPC. Check that the attenuation on the pump line <u>at the pump frequency</u> is not too high. If this line has a low-pass filter, ensure the cut-off is above the pump frequency
- Try repeating the tuning procedure for a different frequency within the amplification range. If gain is achievable there, try moving the gain to the desired frequency by changing pump frequency, pump power, and magnetic coil bias.

I can't get enough gain

- Make sure you are in the regime where gain increases with increasing pump power, and you are taking small power steps (0.01 dBm)
- Check that your VNA power is not saturating the amplifier. Turn the VNA power down and see if gain increases (while keeping the pump settings the same). Continue until gain is independent of pump power
- Slightly change magnetic coil bias (try both increasing and decreasing it in steps of order 0.001 mA) and check if maximum gain is larger by changing the pump power at each new bias point. Depending on where you are on the flux curve, it may take several steps to show a difference. If 0.001 mA steps don't seem to show a difference, try moving in 0.01 mA steps.
- Read through the suggestions in the previous section.

My gain curve is not symmetric

- Slightly change pump frequency or magnetic coil bias. See if symmetry improves. If symmetry degrades, change the pump frequency or coil bias in the other direction.
- Check that your lines are well matched, and do not have any unusual features when the JPC pump is turned off.
- Check the response curve of the JPC with the lines subtracted out. This can be done by turning the JPC pump power off, saving a copy of this background trace to memory in the VNA, and then utilizing the data/memory feature. Now turn the pump back on.

Troubleshooting and FAQ

My SNR has not improved

- Check the JPC has the amount of gain you expect.
- Check that your signal power is not high enough to be saturating your amplifier.
- Look at the output on a spectrum analyzer to ensure you are using enough gain to overcome the noise of the rest of your amplification chain.
- Please note an overly large peak on the spectrum analyzer can also indicate improper biasing. See the ‘Tuning Procedure: Advanced Setup Notes’ section for more details.

I had a good amplification curve, but now the amount of gain I am seeing has changed or the shape of the curve has changed

While these amplifiers are relatively stable, the bias conditions may slightly drift over time, or with changing external magnetic environment. The amplification curve should be checked at least once per day

- If the deviation is small, change the pump power until the desired gain point is restored
- Slightly change the pump frequency and then the pump power until the desired gain point (i.e. the amount of gain, bandwidth, frequency, etc.) is restored.
- Turn off the pump and check that the linear resonance of the device has not moved
- Even with shielding, large changes in the external magnetic field may shift the linear resonance of the JPC. Move the linear resonance back to the desired frequency by changing the bias current of the magnet.
- If the current to the magnetic coil was changed too quickly (for example in the event of a power interruption to the current source) flux may be trapped in the JPC. Ramp down your current supply and turn it off. Warm up your fridge temperature to 1.2 K or above, and then cool back down to base. Returning to an old magnetic current bias should now return your resonator to the expected frequency.

I want to perform a flux sweep.

- Look at the phase response of the JPC at a single current bias. Use the electrical delay feature on the VNA to compensate for the length of the input and output lines, and change the phase offset so the phase roll goes between ± 180°.
- Sweep the bias current of the magnet, and at each new current bias save the phase and amplitude response of the JPC. Typical flux sweeps are between ±2 mA, and the current is changed in 0.02 mA steps.

Troubleshooting and FAQ

- If a resonator is being measured in reflection, you should see a phase response very similar to the one provided, and the amplitude response should be relatively flat. If you are looking at a resonator in transmission (for example if you are using the advanced setup) you will see a response in both phase and amplitude.
- Please note the JPC has three modes, the signal and idler modes will be around the frequencies quoted on page 10. You may also see a response at a frequency in-between the signal mode frequency and the idler mode frequency, which corresponds to the common mode of the JPC. Please do not try to amplify using this mode.

My question was not answered or I'm still having trouble!

- Technical support is available at support@quantumcircuits.com
- Training is also available! Please contact sales@quantumcircuits.com for more information.